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Durban, South Africa

Conference Theme:
Research for inclusive, relevant and equitable quality Mathematics, Science and Technology Education: Promoting research-based opportunity for all

LONG PAPER ABSTRACTS, SYMPOSIA, SHORT PAPERS, SNAPSHOTS

Compiled by M Good & C Stevenson-Milln
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SAARMSTE 2019

Long Paper Abstracts, Symposia, Short Papers, Snapshots

27th Annual Conference of the Southern African Association for Research in Mathematics, Science and technology Education (SAARMSTE)

Tuesday 15 – Thursday 17 January 2019

Hosted by University of KwaZulu-Natal, Durban, South Africa.

Theme: Research for inclusive, relevant and equitable quality Mathematics, Science and Technology Education: Promoting research-based opportunity for all

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Short papers, snapshots and symposia/panel papers are not fully peer reviewed and thus do not attract DHET subsidy.

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All other submissions will be available electronically.
# Table of Contents

## Mathematics Long Paper Abstracts

Jogymol Kalariparampil Alex\(^1\), Nicky Roberts\(^2\) .......................................................... 1
Hanrie Bezuidenhout; Elizabeth Henning; Caroline Fitzpatrick; Lara Ragpot ......................... 2
Jose Luis Cortina\(^1\); Jana Visnovska\(^2\); Mellony Graven\(^3\); Pamela Vale\(^3\) ...................... 3
Beata Dongwi & Marc Schäfer .................................................................................................... 4
Janne Fauskanger & Raymond Bjuland ..................................................................................... 5
Lisnet Mwadzaangati .................................................................................................................. 6
Craig Pournara & Patrick Barmby ............................................................................................... 7
Benjamin Shongwe .................................................................................................................... 8
Florence Thomo Mamba .............................................................................................................. 9

## Mathematics Symposia

Nicky Roberts\(^1\); Hamsa Venkat\(^2\); Mogege Mosimege\(^3\); Marc Schafer\(^4\); Karin Brodie\(^2\) .... 10
Ingrid Sapire; Dineo Makoro; Thompho Rambuda; Benny Mojela; Michael Louw ................... 12

## Mathematics Short Papers and Snapshots

Lawan Abdulhamid .................................................................................................................... 15
Lúcio Afo ...................................................................................................................................... 19
Jogymol Kalariparampil Alex ..................................................................................................... 21
Gabriel Bagwasi\(^1\); Alakanani Nkhwalume\(^2\) ........................................................................ 25
Lynn Bowie Bowie\(^1,2\) Hamsa Venkat\(^1\); Mike Askew\(^1\) .................................................... 31
Tracey Butchart; Craig Pournara; Patrick Barmby .................................................................... 36
Tracey Butchart\(^3\); Craig Pournara\(^2\); Patrick Barmby\(^2\) ..................................................... 40
Clemence Chikiwa\(^3\); Given Matengu\(^2\); Marc Schäfer\(^1\) .................................................. 44
Clemence Chikiwa\(^3\); Aune K Katenda\(^2\); Marc Schäfer\(^1\) .................................................. 49
Samukeliso Chikiwa .................................................................................................................. 55
Mathematics Poster Papers

Jeremiah Madzimure ......................................................................................................................... 328

Science Long Paper Abstracts

David Kaseke¹ & Eunice Nyamupangedengu² ................................................................................... 330
Lydia Mavuru ........................................................................................................................................ 331
Mpho Mosabala ..................................................................................................................................... 332
Mafor Penn¹, Umesh Ramnarain¹ & Hsin Kai Wu² .............................................................................. 333
Maria Tsakeni ........................................................................................................................................ 335
Science Symposia

Audrey Msimanga1; Martin Braund2; Meshach Ogguniyi3 .............................................................. 336
Brighton Mudadigwa1; Jabu Sithole2; Audrey Msimanga1 ................................................................ 340
Marissa Rollnick1; Elizabeth Mavhunga1; Jan van Driel2; Stephen Malcolm1 .................................. 345

Science Papers and Snapshots

Mekbib Alemu Aboretugn1; Vanessa Kind2; Mesfin Tadesse1 (presenter); Mulugeta Atinafu1; Kassa Michael1 .......................................................................................................................... 348
Uchechi Ahanonye; Femi Otulaja; Shalini Dukhan; Ida Risenga ...................................................... 352
Eyitayo Julius Ajayi ............................................................................................................................. 356
Olutosin Solomon Akinyemi & Elizabeth Mavhunga ....................................................................... 356
Bako Nyikun AUDU; Cynthia Fakudze; Mark Herbert .................................................................... 369
Karryn Austen & Megan Doidge ........................................................................................................ 375
Selina Bartels1; Judith Lederman2; Norman Lederman2 ..................................................................... 380
Mesfin Tadesse Beshah1; Mekbib Alemu1; Per Morton (Deceased) Kind2 ........................................ 384
Lubabalo Albert Bhulana1; Audrey Msimanga2; Marissa Rollnick ...................................................... 388
Margaret Blanchard1; Michelle Nugent1; Kathryn Green1; Meredith Kier2 ....................................... 393
Margaret Blanchard1; Kristie Gutierrez2; Christopher Allred1; Kylie Hoyle3 .................................... 399
Anastasia Buma & Eunice Nyamupangedengu .................................................................................. 403
Jó Capece ........................................................................................................................................... 411
Vivien Chabalengula & Frackson Mumba ....................................................................................... 423
Nkosinotshando Chamane1&2 & Lebala Meriam Kolobe2 .............................................................. 427
Agostinho Juliao Chambe & Fernando Antonio Come ....................................................................... 432
Terrence Chigura & Mpunki Nakedi .................................................................................................. 436
Corène Coetzee1; Marissa Rollnick2; Estelle Gaigher1 ........................................................................ 440
Nicole Correia1 & Mpunki Nakedi2 ...................................................................................................... 444
Ibiye Dagogo; Bette Davidowitz; Dale Taylor .................................................................................. 448
Sakiyiwaa Danso & Emmanuel Mushayikwa .................................................................................. 451
Thasmaj Dhurumraj ............................................................................................................................ 455
Gilbert Dolo1; Jesper Haglund2; Konrad Schönborn3 ......................................................................... 460
Washington T Dudu & Kgomotsego Brenda Samuel ........................................................................ 464
Shalini Dukhan ................................................................................................................................... 466
Heba EL-Deghaidy1; Viviana Borges Corte2; Kazumasa Takahashi3; Meshach Ogguniyi4 ............... 470
SAARMSTE Durban 2019
Lindiwe Ngcobo & Lydia Mavuru ................................................................. 642
Kenneth Mlungisi Ngcoza & Zukiswa Kuhlane ........................................ 645
Kristof Shingwilila Nikodemus1; Kenneth M Ngcoza2; Joyce Sewry2 ...................... 649
Eunice Nyamupangedengu; Takudzwa Muvoti (Presenter); Caleb Mandikonza .... 653
Kyle Oerder ...................................................................................................... 657
Meshach Ogunniyi1; Viviana Borges Corte2; Heba El-Deghaidy3; Kazumasa Takahashi Takahashi4 ................................................................. 660
Ademola Olatide Olaniyan & Nadaraj Govender ............................................. 665
William Palmer .............................................................................................. 669
Suzan Pooe ..................................................................................................... 672
Margie Probyn1; & Audrey Msimanga2 ............................................................ 676
Alvin Riffel ...................................................................................................... 679
Shaun Robertson1 & Martie Sanders2 .............................................................. 683
Marissa Rollnick1; Rene Toerien2; Mumba Frackson3; Bette Davidowitz2 ............. 692
Martie Sanders ............................................................................................... 696
Simson Ndadaleka Shaakumeni ....................................................................... 704
Doras Sibanda1 & Marissa Rollnick2 ............................................................... 708
Walter Simango & Mpunki Nakedi ................................................................... 712
Fredrick Simataa Simasiku1 & Kenneth M Ngcoza2 ....................................... 718
Ayanda Simayi & Benedict Khoboli ................................................................. 723
Suresh Singh .................................................................................................. 726
Zamani Sithole1 & Nkopodi Nkopodi2 .............................................................. 729
Angela Stott .................................................................................................... 737
Poncian Obert Tagutanaizvo .......................................................................... 746
Getachew Tarekegn1; Jonathan Osborne2; Mesfin Tadesse3 ......................... 750
Naomi Thomas & Audrey Msimanga ............................................................. 755
Patricia Truzumberah & Audrey Msimanga .................................................... 759
Tholani Tshuma & Eunice Nyamupangedengu .............................................. 764
Denise van der Merwe1 & Elizabeth Mavhunga2 ........................................... 768
Jenny Woolway1; Audrey Msimanga1; Anthony Lelliott2 ................................. 771
Hassen Worku1; Hans Fischer; Mekbib Alemu2 .............................................. 775
Kathija Yassim & Elias Hodi Tsamago ........................................................... 779
Thabiso Lindokuhle Zikalala & Poncian Obert Tagutanaizvo ....................... 783
Mpumelelo Faith Zondi & Elizabeth Mavhunga ............................................. 788
Science Poster Papers

Alberto Boane & Jemisse Tuende ...................................................................................................... 792
Johanna Haimene; Kenneth M. Ngcoza; Zukiswa Kuhlane ............................................................... 797
Angelius Kanyanga Liveve1; Kenneth Mlungisi Ngcoza2 ................................................................ 801
Xolani J. Mayana & Kenneth M. Ngcoza ........................................................................................... 804
Rauha Mika1 & Prof Kenneth M. Ngcoza2 ...................................................................................... 808
Jacqueline Maletsau Mphahlele ....................................................................................................... 812
Ronicka Mudaly ............................................................................................................................. 815
Cecilia Mukundu1 & Audrey Msimanga PhD2 .............................................................................. 818
Rob O’Donoghue; Zukiswa Kuhlane & Prof Kenneth Mlungisi Ngcoza ........................................ 821
William Palmer ............................................................................................................................... 825
Makomosela Qhobela & Eunice Kolitsoe Moru ............................................................................. 829
Lineo Florence Ramasike & Kenneth Mlungisi Ngcoza ............................................................... 833
Fillipus Shetunyenga; Kenneth Ngcoza; Zukiswa Kuhlane ......................................................... 842
Ayanda Simayi ................................................................................................................................ 846

Technology Long Paper Abstracts

Leila Goosen & Dalize van Heerden .............................................................................................. 850
R Maluleke & MT Gumbo ................................................................................................................ 851

Technology Short Papers and Snapshots

Daniel Costa1 & Sérgio Witimisse2 ................................................................................................. 852
Leila Goosen & James Ngugi ......................................................................................................... 859
Avashkumar Juggernath & Professor Nadaraj Govender ............................................................ 868
Petrus Kok ..................................................................................................................................... 872
Malose Kola .................................................................................................................................. 876
Melanie Luckay ............................................................................................................................. 879
Sello Mangwane1 & Thapelo Mamiala2 ....................................................................................... 884
Michael Mokoena1; Laura Coetzer2; Sibongile Simelane-Mnisi2 .................................................... 889
SAARMSTE Durban 2019
Lindiwe Mthethwa ................................................................. 899
Thokozani Mtshali1; Sylvia Ramaligela2; Moses Makgato2 .......................................................... 904
Oswell Namasasu1; Chimbidzikai Wingwiri2; Paul Maribha3; William Chipango4 .................. 908
Asheena Singh-Pillay & Douglas Sotsaka .................................................................................. 909
Rowan Thompson1; Busisiwe P. Alant2; Asheena Singh-Pillay2 .............................................. 913
Sansão Timbane1 & Raquel Scremin2 ...................................................................................... 924

Technology Poster Papers

Esther Shinana & Kenneth M. Ngcoza ....................................................................................... 925
Short Paper & Snapshot Reviewers 2019

The SAARMSTE Review Panel thanks the following short paper reviewers for their time and expertise:

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THE NEED FOR RELEVANT INITIAL TEACHER EDUCATION FOR PRIMARY MATHEMATICS: EVIDENCE FROM THE PRIMARY TEACHER EDUCATION PROJECT IN SOUTH AFRICA

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ABSTRACT

Recently, initial teacher education for primary mathematics teachers has drawn much attention worldwide due to its importance and contribution to childhood development. In South Africa, in response to a quest for relevant and quality primary mathematics teachers, the Primary Teacher Education (PrimTEd) project has been established as a collaboration between all higher education institutions (HEIs). Different workstreams in PrimTEd are mandated to develop sets of commonly agreed standards, materials and assessments of knowledge for teaching primary mathematics. A common assessment in mathematics was deemed necessary to allow each HEI to reflect on their student intake, and design of their Bachelor of Education programmes (B.Eds). The assessment workstream constructed an online test of 90 minutes, consisting of 50 items on different mathematics concepts pertaining to foundation and intermediate phase school mathematics for teaching. The authors, analysed the performance of the 2017 pilot testing with first year students (n = 317) from two universities, and the 2018 national assessment (n = 1 117), where students from seven higher education institutions participated. The results from the 2017 pilot (𝑥̅ = 45.89%, SD = 14.8) and 2018 national assessment (𝑥̅ = 48.46%, SD = 16.8) reveal similar patterns of performance. As the test was set at the level of mathematics at which the students are expected to teach, it is concerning that the majority of students (71%) were not able to obtain more than 60%. This brings into question the assumptions made about the mathematics skills and competencies that entrants into the B.Ed programme bring with them into tertiary education. It is recommended that the lower than expected starting point, should be taking into account, when reflecting on the relevance of the preparation of primary mathematics teacher education for quality teachers of primary mathematics in South Africa.

Keywords: Primary mathematics education; PrimTEd project; assessment; initial teacher education; relevance; South Africa
EARLY MATHEMATICS VOCABULARY AND NUMBER CONCEPT DEVELOPMENT

Hanrie Bezuidenhout¹; Elizabeth Henning²; Caroline Fitzpatrick³; Lara Ragpot⁴

ABSTRACT

Many South African, grade R children fail to develop early number concepts that are a prerequisite for mathematics learning in the first grade. The same children may also enter formal education without adequate cognitive skills that are known to support mathematics learning. This paper theorizes that mathematics vocabulary, logical reasoning and classroom engagement (as output of the cognitive skills known as ‘executive functions’) are important skills for early number concept development. Although multilingual classrooms can be utilized for rich learning opportunities, they may also add to children’s ‘linguistic maze’. A theory of translanguaging describes how children can access various linguistic features or different autonomous languages, to maximize communication. The paper extends the theory of translanguaging to the domain of early number concept development and presents a hypothesis, suggesting that, together, an elaborated mathematics vocabulary, logical reasoning, and skills of executive functions significantly contribute to early number concept development. We make suggestions for improving underperforming young South African children’s mathematics understanding, specifically regarding expansion of their linguistic code, enhancing classroom engagement, and developing logical reasoning skills.

Keywords: maths vocabulary, classroom engagement, logical reasoning, number concept development, kindergarten, translanguaging, code-switching, individual differences

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INSTRUCTIONAL DESIGN IN PURSUING EQUITY:
THE CASE OF THE ‘FRACTION AS MEASURE’ SEQUENCE

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ABSTRACT
The aim of this paper is to discuss an approach to instructional design in which we intertwine mathematics education research with development, draw insights from collaborations across international contexts, and place educational equity firmly at the center of our work. Using an example of the instructional sequence on ‘Fraction as Measure,’ we illustrate how the two key aspects of the design process allow for developing instructional resources with equitable learning opportunities in mind. The two aspects entail specifying (a) the prospective endpoints of an instructional sequence (i.e., forms of students’ reasoning to be developed), and (b) how the learning process might be realized in the classroom, so that students would come to develop the specified forms of reasoning. We discuss how considerations of teacher learning, and processes of travel and scaling up of designed instructional innovations, need to be considered by designers aiming to advance educational equity.
USING ENACTIVISM TO THEORISE THE RELATIONSHIP BETWEEN VISUALISATION AND REASONING PROCESSES WHEN SOLVING GEOMETRIC TASKS

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ABSTRACT
This paper reports on the first two phases of a bigger PhD study that analysed the relationship between visualisation and reasoning processes when solving geometry word problems. For the first phase of the study, the participants consisted of 17 mixed-gender and mixed-ability Grade 11 learners from a private school in southern Namibia. For the second phase of the study, 8 of the original 17 were selected to participate. These participants answered geometry word problems individually and in small groups by making use of visual imagery as they reasoned their way through a problem. Analysis of the participants’ responses to the word problems was informed by elements of enactivism and consisted of a hybrid of observable visualisation and mathematical reasoning indicators. The key enactivist concept of co-emergence was one of the mediating ideas that enabled this analysis and the discussion of the links between visualisation and reasoning that emerged. The study argues that the visualisation processes enacted by the participants while solving such problems are inseparable from the reasoning processes. They are thus closely interlinked in the process of engaging in any mathematical activity – they co-emerge.

Keywords: enactivism, visualisation, mathematical reasoning, visual imagery, co-emergence
LEARNING TO ELICIT AND RESPOND TO STUDENTS’ MATHEMATICAL IDEAS THROUGH TEACHER TIME-OUT

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ABSTRACT
This study explores the potential for mathematics teachers to learn ambitious teaching practices together with students and through the routine Teacher Time-Out (TTO). Since ambitious goals for students’ learning requires ambitious teaching practices, studying potentials for learning such practices is important. The data material analysed, is taken from the project Mastering Ambitious Mathematics teaching (MAM). In this project, teachers work on given teaching activities in cycles of enactment and investigation. In this paper, the enactments are analysed and in particular the parts of the enactments where the participants pause instruction for by asking for a TTO. From 139 TTOs in total, 21 TTOs from one cycle are analysed in-depth, suggesting that the routine is a context for teachers’ opportunities to learn how to elicit students’ mathematical ideas and ways to respond to students’ mathematical ideas – in particular how to provide written responses to students’ mathematical ideas. Implications are discussed.
AN EXPLORATION OF PEDAGOGICAL CONTENT KNOWLEDGE FOR TEACHING OF SECONDARY SCHOOL GEOMETRIC PROOF DEVELOPMENT IN MALAWI

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ABSTRACT
This paper presents findings from a qualitative case study of exploring aspects of knowledge involved in the pedagogical content knowledge category of explaining and representing geometric proofs. Data were generated by interviewing four Malawian secondary mathematics teachers about their views on knowledge for teaching geometric proof development and observing their lessons. The findings suggest that knowledge of explaining and representing geometric proof development involve several aspects. These include; knowledge of aspects to be emphasised during teaching of geometric proving; knowledge of proving activities; knowledge of explaining geometric proof concepts as connected entities; knowledge of inductive and deductive forms of representing geometric proofs; knowledge of relevance of geometric proofs; and knowledge of teaching materials.

Keywords: Geometric proof development, Pedagogical content knowledge
NO SIGNIFICANT IMPACT ON LEARNER ATTAINMENT – REALLY? A QUASI-EXPERIMENTAL IMPACT STUDY OF A PROFESSIONAL DEVELOPMENT COURSE FOR SECONDARY MATHS TEACHERS

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ABSTRACT
We report on the impact of a mathematics professional development course on secondary teachers’ mathematical knowledge and on their learners’ attainment. The teachers’ scores on a mathematics test improved significantly as a result of their participation in the course. In turn, using a quasi-experimental study we examined the learning gains of approximately 1000 Grade 9 learners from nine secondary schools taught by teachers who had attended the course. We compared these results with those of a comparison group of approximately 1000 learners in the same schools taught by teachers who had not participated in the course. While the intervention group made larger gains, these gains were not statistically significant in comparison with the control group. A closer investigation of the teaching experience of the teachers who had participated in the course compared with their colleagues in the comparison group showed that those in the comparison group had considerably more experience in teaching Mathematics at Grade 10 to 12 level. This suggests that the intervention cannot make up for the experience of teaching mathematics at senior secondary level in the first year after completing the course. It also points to the importance of identifying a matched comparison group of teachers when conducting quasi-experimental impact studies of professional development.

Keywords: Learning gains, mathematics teacher knowledge, impact of professional development
THE QUALITY OF ARGUMENTATION IN A EUCLIDEAN GEOMETRY CONTEXT IN SELECTED SOUTH AFRICAN HIGH SCHOOLS: VALIDATION OF A RESEARCH INSTRUMENT

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ABSTRACT
The research reported in this study examines the nature of Grade 11 learners’ argumentation features and characterises the quality of argumentation in selected Dinaledi high schools in an effort to adapt and validate a research instrument. Mathematics education reform efforts have highlighted the importance of argumentation in the acquisition of mathematical knowledge. This is attested to by the Curriculum and Assessment Policy Statement’s (CAPS) prescription of investigations as one of the central elements of the mathematical activity. However, very little is known about the quality of mathematical argumentation in high school mathematics classrooms. To add to the literature on argumentation in mathematics from a South African perspective, a survey questionnaire was used to adapt and validate an analytical tool on the quality of argumentation. The data were examined through the lenses of Toulmin’s argumentation scheme and an analytical tool adapted from Osborne, Erduran, and Simon’s framework. The findings suggest that learners hardly construct rebuttals and that the level of their argumentation is low. These results suggest that this tool can be used as a reliable assessment and diagnostic tool in both instructional practices and mathematics education research. The study recommends the consistent use mathematical investigations as a platform to develop argumentation skills in learners. The implication for this recommendation is that mathematics teacher education programmes need to enhance preservice teachers’ engagement in investigations so that learners can argue with purpose. The discussion highlights the implications of this recommendation. Future research on argumentation is explored.

Keywords: Validation; argumentation quality; triangle sum conjecture; investigation; mathematical knowledge construction
A PRE-SERVICE TEACHER’S ORCHESTRATING CLASSROOM DISCUSSION WHEN TEACHING LINEAR EQUATIONS

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ABSTRACT
This study investigated a preservice secondary school teacher’s practice of orchestrating classroom discussion when teaching linear equations. Data were generated using video lesson recordings of nine lessons and were analysed using thematic analysis. Themes were developed a-priori from the theoretical framework and a-posteriori from the data. Findings show that the preservice teacher’s capacity to orchestrate classroom discussion was influenced by his mathematical knowledge for teaching. In particular, the preservice teacher anticipated what students would do by focusing on the correct solution processes but did not plan for expected students’ errors and misconceptions. In addition, the preservice teacher monitored students’ work by listening, observing students’ work, and asking the students to explain their solution processes but did not keep track of students’ approaches because of lack of analysis skills and questions that could elicit students’ reasoning and arguments. The preservice teacher also selected certain students to solve problems on the chalkboard in order to find out if the students knew the “correct” solution process of a particular problem. Furthermore, the preservice teacher attempted to draw connections between algorithms but did not draw connections between students’ mathematical ideas and other students’ ideas because he did not give students opportunities to present their work. Implications of these findings for mathematics teacher preparation are discussed.

Keywords: Orchestrating classroom discussion, mathematical knowledge for teaching, preservice teacher, secondary school, linear equations
THE PEDAGOGY OF MATHEMATICS IN SOUTH AFRICA: IS THERE A UNIFYING LOGIC?

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This panel discussion will focus on mathematics pedagogy, which is interpreted in the broad sense of interaction between society and its values. Our use of pedagogy is not in its narrow definition of our ideal classroom pedagogy or approach to mathematics learning and teaching. We use pedagogy in, the sense of Alexander (2009), as a trans-interaction between society and the societal values located in the nation state.

In a recent edited volume, Webb & Roberts (2017) suggested that as South Africans we must proactively forge a long-term vision and plan for a state that no longer suffers from such a severe crisis in mathematics education. They – and the contributing authors - asked: ‘Is it possible that South Africa might achieve a unifying pedagogy for mathematics, which informs state decision-making?’

This panel will reflect on this question from the perspectives of some of the contributing authors to this volume and solicit discussion from the participants on their perspective on it.

Planned format: 10 minutes per panellist and 40 minutes for discussion and engagement between panellists and audience

PANELLIST 1 focuses on concerns relating to progression, connection and coherence. She argues that the somewhat linear reading of progression as requiring a move from ‘concrete’ to ‘semi-concrete’ and then to ‘abstract, symbolic’ representations – something that is echoed in curriculum documents and in Foundation Phase teacher education – may be problematic. She advocates for teacher talk that is well connected to the use of resources and written inscriptions in ways that are responsive to and contingent upon what learners offer in classrooms. She also emphasises the teacher’s role in supporting meaning-making in relation to quantities and operational relationships. Evidence of concern about primary teachers’ mathematical knowledge and suggestions that teacher education programmes ought to focus on content for the teachers at the same level at which the teachers are teaching (i.e. Foundation Phase for Foundation Phase teachers and Intermediate Phase for Intermediate Phase teachers are presented.

PANELLIST 2 approaches her reflection on mathematics pedagogy as both an academic and a human project. She describes mathematics pedagogy as a three-way relationship between learner, teacher, and subject situated within their contexts, and appeals for an engaged curriculum rather than a compliance curriculum. Mathematics is seen as a living discipline that must be continuously changing or it will die. She recognises teachers and teacher knowledge as areas of concern but emphasises the constraints within which they work. She highlights the current assessment regime that requires much catching up by learners but where little support is offered; poverty; schools as sites of violence and
abuse; and both teacher and learner dislocation and identity. She notes that learners and learning are the least researched component of pedagogy and argues that we do not yet have a sufficiently differentiated understanding of who our learners are, their strengths and needs, and how their backgrounds and contexts influence their mathematics learning.

PANELLIST 3 highlights the fact that the South African mathematics curriculum requires the valuing of indigenous knowledge systems and the acknowledgement of the rich history and heritage of our country. He describes the methodological approaches adopted by ethnomathematics and provides concrete examples of those kinds of studies. He explains that ethnomathematics revolves around two forms of analysis: mathematical traditions that survived colonisation and mathematical activities in people’s daily lives; and cultural elements that may serve as a starting point for mathematics in and outside of school. In that way, the boundaries between the past and present, as well as between the school and the community, are blurred. While much has been done in ethnomathematics, He argues that more is required and that mathematics teachers can play a key role in that endeavour. That has implications for classroom pedagogy: when mathematics educators go into the mathematics classrooms to interact with the learners they are not simply imparting mathematics content. Rather, they are undertaking an activity in which they engage Africans (themselves and their learners) in the formidable task of reclaiming their heritage and of restoring African pride in attaining mathematical knowledge.

PANELLIST 4 approaches mathematics pedagogy by focusing on visualisation, a cognitive area that complements language. He briefly outlines some theoretical aspects of visualisation and then focuses on an online resource (VITALMaths) that is freely available to teachers and learners. He asserts that the explicit use of visualisation processes in our teaching is often neglected and results in a learning environment that is not only sparse visually, but also conceptually. He discusses how short video clips from the VITALmaths project can be used as visualisation tools to enhance mathematical curiosity in the classroom. He also illustrates how mathematics pedagogy needs to change to consider information and communication technologies (ICTs) and how those tools can be harnessed to support mathematics learning.

PANEL CHAIR will open to the floor and panelists for discussion on:

- What is our collective vision toward a unifying pedagogy for mathematics?
- What could we agree are key elements/attributes of a hoped for South African pedagogy?
- What the pockets of commonality or areas of clear divergence which we can identify?

REFERENCES
THE LANGUAGE USE DEBATE – TRANSLANGUAGING OR CODE-SWITCHING IN THE FOUNDATION PHASE?
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The project Researching Multilingualism in FP Mathematics, in its second year at a South African university, undertook two research tasks in 2018 to investigate the use of language in Foundation Phase (FP) mathematics classrooms. The research team carried out interviews and observations in 20 schools in order to investigate ways in which language is used by teachers and learners in the learning of mathematics. This symposium will present some of the project findings and provide an opportunity for debate on the use of the terms translanguaging and code-switching to describe language use in the context of FP mathematics lessons.

INTRODUCTION

Concrete experiences are central to the learning of foundational mathematics concepts but the thoughts and ideas related to these experiences must be expressed using language. Learners, guided by their teachers, listen, think and talk, as they manipulate concrete materials. Language is central to learning. The post-apartheid Language in Education Policy (LiEP) (DoE, 1997) promotes the development of all eleven South African official languages (Alexander, 1989; Plüddemann, 2015). In accordance with this policy, the Department of Basic Education (DBE) curriculumpolicy states that mathematics teaching in the FP should be in the home language of learners (one of the eleven official languages of South Africa, or sign language). On the ground, the outworking of this policy narrows down the choice of language to one language per class, the chosen Language of Teaching and Learning (LoLT). This presents an empirical problem: although there is a spread across all eleven official languages nationally in FP classes, current policy interpretation and implementation, specifically the way in which the LoLT is selected (and learning material are produced), imposes monolingual education. A theoretical issue that arises when researching this problem relates to the conceptual resources for the discussion of the use of language – specifically in the distinctions between the concepts of translanguaging and code-switching is not clear which makes them difficult to operationalise.

Literature review

Whatever the language of expression might be, the literature supports the idea that spoken language needs to be used in such a way that learners are able to express their thoughts as clearly as possible, while they grapple with the mathematical concepts that they are learning. The use of language should not interfere with the learners’ ability to speak about what they are doing and make conceptual generalisations (for an overview of this research see Essien, 2018).
Language use in South Africa is predominantly pluralist. This means that many South African learners (and teachers) use more than one language when they speak to communicate that which they want to say (Phakeng, 2017). A single LoLT, to be used exclusively in the teaching of an FP class, does not make provision for flexible language use. In South Africa, where there are eleven official languages, the question is not necessarily ‘which language’ but possibly ‘what repertoire of languages’ would best enable young learners to learn their mathematics? There are different ways in which speakers may use more flexible, pluralist, practices – in linguistics and other fields where language use is researched the terms code-switching and translanguaging are used to describe these flexible language practices (Garcia & Wei, 2014).

The term code-switching has been in use longer, originating in the field of linguistics. In the 1940s and 1950s it was regarded by some as an inferior use of language but since the 1980s it has been regarded as a normal, functional use of language by bilinguals (Gumperz, 1982) in that it enables them to draw on other languages they know when learning in a language that is not their main language. The term translanguaging is a more recent term used to describe multiple language practices. It originated in Wales in the 1980s and the term is said to be a translation of the Welsh word trawsiethu coined by Cen Williams when he and his colleagues were researching strategies of using both Welsh and English in a single lesson in a classroom setting. Code-switching can be seen as external function where speakers of more than one language switch between their languages (Gumperz, 1982, p.59) to express themselves. Translanguaging is seen as an internal strategy by which speakers use all of their linguistic resources to communicate (Garcia & Wei, 2014; Makalela, 2015; Williams, 2002). There is not full agreement in the literature on whether or not code-switching is part of or separate from translanguaging but sociolinguistics can be productively used to inform the analysis of bilingual mathematical conversations (Moschkovich, 2005).

Symposium discussion and debate: Team member contributions
Team leader: project overview, introduction and background. The literature on which the research is based will be presented. The team will then present interim findings from the two 2018 project research activities carried out in 20 Gauteng schools.

Interviews: three student team members will present the methodology and interim findings of this task. The methodology comprised open-ended interviews carried out with 44 Grade 3 and 27 Grade 4 mathematics teachers to investigate teachers’ views on how they and their learners communicate mathematical concepts in multilingual classrooms, within the constraints of policy, vocabulary, language use, and classroom practice. The team recorded and transcribed the interviews. Team analysis meetings were held to draw up a consolidated report of the findings. Findings show that many teachers feel comfortable using mixed language practices while some prefer using pure language. Teachers questioned the validity of the current policy saying that it imposes unrealistic constraints and creates tensions in classrooms due to curriculum overload. The teachers strongly believe that home language mathematics vocabulary is not sufficiently standardised. The say that learners often understand the mathematics but struggle with the language. Some teachers say that code switching can help learners to understand concepts better while others say that it creates confusion. Several teachers indicated that using concrete aids while speaking about concepts assisted learner understanding. Many teachers believe that the current multilingual composition of classes benefit from heightened use of English, as it is the one language most learners would understand.

Observations: three student team members will present the methodology and interim findings of this task. The methodology comprised video observations in the classes of all interviewed teachers who
agreed to allow the research team to video them in their classrooms (29 teachers). In this presentation we report on a subset of 18 of those observations. Lessons were video recorded, transcribed and coded for the purposes of analysis. Codes were developed over a period of weeks of team coding, after which team members coded lessons independently since consensus had been achieved on the codes. Descriptive data of the lessons was summarised. The lessons were on the topic of patterns. Variations in the examples used and explanations given were noted. Findings show that the lessons were predominantly interactive but with the teacher leading the discussion. Use of language was similar in grade 3 and 4, with similar percentages of teachers using pure language (43%) and translanguaging (39%) and a smaller percentage using code-switching (18%).

African languages dominated in Grade 3 and English dominated in Grade 4. Concrete materials were used more in Grade 3 than Grade 4.

**Discussant:** to respond to issues raised in connection with the theoretical conceptualisation of language use.

**Symposium group activity:** The analysis of interview data shows that teachers refer to code-switching more often when they refer to mixed language practices while the literature is moving towards the use of the term translanguaging, which is seen as a more open and flexible way of thinking about language use. The team will facilitate hands-on analysis of observation data using excerpts from transcriptions of observed lessons, which will be provided. This will allow participants to analyse, discuss and debate different kinds of language use.

**REFERENCES**


**INTRODUCTION**

A recent review of the literature on basic education in Nigeria has shown that mathematics attainment levels in public primary schools are below the competencies specified in the curriculum (Humphreys & Crawfurd, 2014). This is leading to more recent policy attention, at the state level, to questions about primary teachers’ mathematical knowledge and classroom practice skills (NAN, 2017). On the research side, there is a gap with more studies in Nigeria focused on pedagogic ‘form’ with limited focus on disciplinary teaching and teachers’ ways of handling mathematics content. Within the broader context of poor performance in mathematics, a research and development project – the Abubakar Tafawa Balewa University Maths Improvement (ATBU-MI) project was launched in 2017 aimed at improving the teaching and learning of primary mathematics. As part of the baseline data collected for this project, the project team observed and video recorded 19 primary mathematics lessons dealing with multi-digit addition and subtraction across Grades 2 and 3 classes in the eleven project schools, with a view to gaining insights about the nature of mathematics teaching.

Multi-digit addition and subtraction was selected as these topics form a substantial part of the focus of early grades’ mathematics. Further, the teaching of early addition and subtraction has been written about widely in the international literature, with critiques of early introduction of column algorithms (Hiebert & Wearne, 1996; Dalton, 2008; Thanheiser, 2009) because of the danger of their sidelining of number sense if ‘digit’-based working is foregrounded. Alternative pathways advocated for multidigit addition and subtraction teaching are based on attention to number structure and relations, for example awareness of the base ten relationships that allow for fluent composition and decomposition to the nearest ten and counting in tens (Hiebert & Wearne, 1996; Thanheiser, 2009). Of interest in relation to this literature is the Nigerian curriculum’s promotion of column algorithms from Grade 2 onwards (NRDCE, 2012).

In the South African context where low performance has also been a concern, Venkat & Askew (2018) have focused their analyses of primary mathematics teaching on goals of structure and generality, with attention to the ways in which pedagogic mediation across a range of semiotic forms allows for...
coherent, connected and responsive working. Their ‘Mediating Primary Mathematics’ (MPM) framework provides a tool for analysing teaching for structure/generality via several mediating strands. In this paper, I present an analysis of one grade 2 lesson as an illustration of teaching that bypassed attention to structure and relations in the teaching of multi-digit addition algorithm.

CONCEPTUAL FRAMEWORK

The MPM framework (Venkat & Askew, 2018), is based in a sociocultural view of instruction focusing on mathematical structure and relations, with mediational moves towards generality. Mediation in the MPM framework involves both explicit and the implicit forms. Explicit mediation involves pre-planned artifacts or manipulatives that are used in episodes of teaching, and implicit mediation forms are inscriptions and teacher talk/gestures, with greater potential for responsive adaptation in the moment of teaching.

In this paper, I focus on the ‘implicit’ mediation strands, as there were no pre-planned artifacts used in any of the observed lessons. These are:
- inscriptions – what the teacher writes on the board/resources created in the moment of teaching
- teacher talk/gesture - this involves three sub-strands: methods for generating or validating solutions, mathematical connections, and learner-level connections.

Venkat and Askew (2018) categorise the extent and nature of mediation, in an analytical rubric, with levels and indicators that supported focus on structure and relations that lead to generality.

DATA SOURCES

Data are drawn from video recordings of primary mathematics lessons across Grades 1-3 classes in the 11 project schools in the ATBU-MI project’s baseline data (n=52). 19 grade 2 and grade 3 teachers were video recorded teaching multi-digit addition or subtraction, all involving column algorithms. One episode with teacher Z, typical of the broader dataset, is analyzed in this paper, as a ‘telling case’ (Sheridan, Street, & Bloome 2000).

ANALYSIS AND FINDINGS

The lesson focused on what Ms Z called ‘addition of 3-digit numbers with renaming’. Two examples; 768+225 and 668+214 were completed on the board as a whole class activity. In the first example, 768 + 225 was written on the board in a column addition format, which is then broke down into place values (see Figure 1).

![Figure 1: Horizontal decomposition of 3-digit numbers into their place values](image-url)
Ms Z proceeded, pointing to vertical addition: ‘We are going to add, we start with eight plus five?’ Ms Z drew eight and five tallies and said, ‘here is the eight’, she pointed to the eight tallies without counting, and then counted on the five tallies, ‘nine, ten, eleven, twelve, and thirteen’. Ms Z moved on to the expanded tens column (60 + 20), she said, ‘zero plus zero’, Learners responded ‘zero’, and ‘six plus two?’ Learners responded eight, which was recorded. Pointing at 700 + 200, Ms Z said, ‘zero plus zero, zero plus zero, and then seven plus two, with learners giving her the digit answers. On completion, Ms Z asked, ‘what is nine hundred plus eighty plus thirteen?’ Learners responded in chorus, some heard saying ‘nine hundred and eighty-three’ and others saying ‘nine hundred and ninety-three’. Pointing to one learner to respond, the offer of ‘one hundred and ninety-three’ was accepted by Ms Z and written in as ‘993’.

Z returned to the compressed column addition as in the left side of Figure 1. She then said, ‘what is eight plus five?’ Learners responded, ‘Thirteen’. Z wrote down 3 and said, ‘we carry one’. She then moved to the tens column, ‘six plus two?’ Learners responded ‘eight’, and she said, ‘plus one that we carried is nine’. ‘What is seven plus two?’ Learners responded, ‘Nine’. Z wrote down 9. She then said, ‘Nine hundred and ninety-three is the answer’. Ms Z moved on to the second example, 668+214, and it was enacted in the same way.

Analysis of teaching mediation

The lesson enactment showed a move by the teacher to establishing the ‘quantity value’ of the digits in the two numbers assembled into a horizontal decomposition. However, quantity does not firmly stay in place, particularly in a situation of vertical addition operation of the tens and hundreds. Ms Z dealt with the numbers as individual digits, losing the quantity value of the numbers. For example, in the case of ‘60+20’, Ms Z says, ‘zero plus zero’ and ‘six plus two’. The teacher talk, in relation to the ‘quantity value’ of tens and hundreds disappeared, as it is being treated here as ‘units’.

For many learners, it appeared to be unclear as the change of 80 to 90 in the 900+80+13 to produce 993 as the answer. This is simply because the moving of the ten from the unit column to the tens has not been dealt with. The number 13 in the unit column needed to be decomposed into 10+3, so that the 10 can be moved to the tens column and added to 80 to make 90. Establishing the equivalence between 900+80+13 and 900+90+3 is critical in this context. Similarly, when talked about ‘carrying’ in working out the compressed column addition, still Ms Z never made reference to the split of 13 into its place value, rather said, ‘Write 3 and carry 1’. Therefore, a critical teaching point where mediation is needed, particularly with the evidence of incorrect answer has not been attended to.

Hence teaching can be described as limited in relation to establishing structure and relation in generating mathematical solution.

CONCLUSION

In conclusion, structured inscriptions (decomposition of 3-digit numbers into their place values) was used, but supplemented with unstructured inscriptions – the tallies. A horizontal mathematical
connection was made in the place value decomposition, however vertical disconnections were seen in first losing the quantity of the numbers within the addition operation, whereby the teacher bypassed the structure of the digit, as treated as units. Secondly, lack of link between the traditional ‘carrying’ in compressed column addition, and the split of 13 into 10+3 and moving the 10 to the tens column indicates disconnection in generating solution.

REFERENCES


FACTORS ASSOCIATED WITH PUPIL’S PERFORMANCE IN MATHEMATICS
(A DATA EXPLORATION OF THE 3RD GRADE NATIONAL ASSESSMENT IN
MOZAMBIQUE IN 2016)

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EXTENDED ABSTRACT

The present study fits into the area of school effectiveness in primary education. It was motivated by the profound changes in basic education in Mozambique, with the introduction of the new curriculum in force since 2004. One of the important milestones of the implementation of this new curriculum is the low level of retention in the grades that compose it promoting through this way a low dropout rate (MINED, 2003). A few years after the introduction of the changes proposed by this curriculum, a common mark of the public reaction regarding to them is manifested in the questioning of the quality of education characterized by low levels of competence in reading and mathematics in the initial classes. Findings of the 3rd National Assessment in 2013 pointed to 8 in of 10 pupils (82.3%) in Level 1 of Portuguese Language skills - Recognition of alphabetical system conventions, and no more than 1 in 10 (6.3%) in the Level 3 - Reading, understanding and analysis (MINED/INDE, 2013). In a similar assessment three years later, the results pointed to 83.8% in Level 1 and only 4.9% in Level 3 of competences (MINED/INDE, 2017). With regard to the mathematics, one example is that the performance of 6th grade pupils in Mozambique has significantly reduced from 2000 to 2007. The mean score dropped down from 530 (2.08) in 2000 to 483.8 (2.29) in 2007 (PASSOS et al, 2011).

The aim of the study is to evaluate the effect of the characteristics of the school and the student on the school performance of this in Mathematics. Although the results of the 3rd Grade National Assessment, both in 2013 and 2016, indicated that there is a greater variation in the performance of the pupils according to the school’s characteristics than those of the student, and the modeling of the factors associated with performance has been done by recurring to Multilevel Regression, the variables were not explored in the same perspective of this paper. The research question posed in this paper is: How do the characteristics of the school and the student affect their school performance in mathematics?

The conceptual framework of the research is based on the model of Scheerens (1990), called the Integrated Model of School Effectiveness. In this model, the indicators associated to the pupil’s school
performance (output) are analyzed taking into account a structure of inputs and processes. The model is based on the assumption that the school is a system in which there are processes (or treatments) that aim to operate transformations that reinforce the effectiveness and output measures usually expressed in terms of the pupil’s school level (SCHEERENS, 2003).

The data from this study refer to the school population of the public-school system in Mozambique in 2016. These are secondary data provided by the National Institute of Education Development (INDE) and also include data provided by the directors/managers of the schools sampled, teachers of selected students, as well as their school’s characteristics. 400 schools were selected for the 2nd National Assessment of the 3rd class, with the participation of 10000 pupils (what corresponds to the participation of 25 pupils per school) in the 3rd class, 590 teachers and 425 school directors/managers. The data collection instruments were developed by the INDE and are divided into four categories: a mathematics diagnostic test, a teacher questionnaire, a school management questionnaire, and a school information bulletin. The mathematics test consisted of a total of 24 questions assessing three levels of competence: Level I - Identification of geometric figures; Level II - Reading and classification of numbers, and level III - Troubleshooting.

The data has a multilevel structure. We consider in this context, the student in level 1 and the school in level 2 (SHALABI, 2002). That’s why the analyzes are carried out based on hierarchical linear modeling in two levels. Once the variables correlated with performance in mathematics have been identified, a hierarchical regression exploration allows explaining a quantity of variance and the marginal effect of each.

There are basically two aspects that motivate this research: (i) from the point of view of levels of analysis we intend to place more emphasis on the multiplicity of levels of school nature, especially with regard to the pupil and the school itself, and (ii) from the point of view of theoretical background, provide information on how individual factors interact within the school context influencing the pupil performance.

The results showed that the results of mathematics generally preserve the pattern observed in the language skills, where 9 in of 10 pupils (89.4%) showed that they have first level competences, 5 in 10 pupils (50.3%) in the level II and less than 1 in each 10 pupils (7.71%) showed that they master the level III. From the perspective of the conceptual framework of the research, it is hoped that the results found reinforce the design of basic policies in order to lead the school to increase the pupil’s performance in mathematics.
ABSTRACT
Internationally, challenges in the preparation of mathematics teachers is not a new area of concern. There is a widespread assumption that having a university degree in mathematics is sufficient to teach senior secondary school mathematics. This assumption is challenged by the perspectives of a group of mathematics education students on the mathematics modules taught to them to become mathematics teachers in senior secondary schools. This paper provides a brief overview on the views of 3rd year Bachelor of Education (BEd, Mathematics Education) students on their content and curriculum studies modules and the training given to them as emerging mathematics teachers during the four years of their course. Data were collected from a sample of 95 student teachers using a self-developed open-ended questionnaire. The students’ perspective shed light to the ongoing debate on ‘what mathematics’ to be taught in the university and recommends that the education community needs to pay more attention to the critical link between the Specialised Content Knowledge (SCK) and Knowledge of Content and Teaching (KCT) and the teacher education curricula in order to prepare the emerging teachers effectively.

Keywords: Mathematics Education modules; relevant curriculum; student teachers’ views; Specialised Content Knowledge and Knowledge of Content and Teaching

INTRODUCTION AND BACKGROUND
Preparing teachers to teach mathematics effectively is one of the most urgent problems faced by those who wish to improve students’ learning (Morris, Hiebert & Spitzer, 2009). Teachers are the determining factors of successful educational change within education and training system so that promotion of teachers though education is a method to access to optimal and successful educational changes (Mostafa, Javad, & Reza, 2017). Preservice experiences at the undergraduate level need to be coordinated, in both a practical and theoretical sense, with teachers’ initiation into the profession in schools, as well as with their continuing education (National Research Council (NRC), 1996). Both the theoretical and practical components of the training program need to be compatible with the work expected of teachers in schools (Nkambule, 2017). Based on the idea that teachers teach as they have been taught (Brown & Borko, 1992), secondary mathematics teachers must have content knowledge, pedagogical knowledge, and pedagogical-content knowledge (Latterell, 2008). The
studies on teacher knowledge also support the fact that pedagogical content knowledge involves in knowledge of pedagogy, content, curriculum, student and other educational issues (Ball, Thames, & Phelps, 2008). Against the forgoing argument on what to be taught to the mathematics education students for relevance and quality, the following research question was addressed: What are the B.Ed. students’ perspectives on what mathematics should be taught to them in their Mathematics B.Ed. Course at the university?

Teacher education component in the higher education landscape in South Africa
In South Africa, traditionally, in the Bachelor of Education courses, content and pedagogy are incorporated into the modules, called content modules and curriculum studies modules respectively. Mathematics teacher education is premised on the assumption that one has to be educated in mathematics in order to be able to teach it (Mgombelo & Buteau, 2009). Teacher education programmes are normally designed to incorporate three distinct yet interrelated domains, namely subject matter (content); theories of teaching and learning (pedagogy); and professional experience (the practicum) (Zinn, Geduld, Delport, Jordaan, 2014). According to Du Plessis (2016), previous school experiences, as well as what prospective teachers experienced at university or college, appear to influence their practice.

THEORETICAL FRAMEWORK
What type of knowledge that a teacher should know (Shulman, 1986; Ball, Thames, & Phelps, 2008) and more especially “What Mathematics” should a teacher know (Ma, 1999), has been the area of research for decades and many researchers and educationalists have come up with theories which have been the foreground of many teacher education courses around the world. It is argued that the particular knowledge needed for effective teaching, and the way in which this knowledge is held, is quite specific, and that this knowledge should form part of teacher education courses at all levels (Ball et al., 2008). Being able to do the mathematics oneself is not the same as being able to enable others to do it. McDiarmid, Ball, and Anderson (1989) posit that teachers’ subject matter has a critical influence of understanding on their pedagogical orientations and decisions. This present study would like to adopt the domains proposed by Ball, Thames and Phelps (2008) which is a refinement on Shulman’s theoretical perspective on teacher education with particular focus on the “Specialised Content Knowledge (SCK) and Knowledge of Content and Teaching (KCT).

METHODS
The study followed an interpretivist paradigm and qualitative approach. Data were collected using a self-developed open-ended questionnaire from a sample of 95 third year mathematics education student teachers who voluntarily took part in the study. While they were at schools, they were following the National Curriculum Statement (NCS) curriculum. During their 3rd year of study the school curriculum was changed to Continuous Assessment Policy Statement (CAPS) which had new
demanding topics than what they had learnt at schools. The views of the above sample of student teachers on their course modules and the course modules for mathematics education offered at the university were analysed. All ethical requirements were met.

FINDINGS

The findings of the study revealed that most of the student teachers were dissatisfied with the mathematics content modules taught to them as the content needed in the school mathematics curriculum was lacking in their university curriculum and that they do not get prepared adequately to become senior secondary school mathematics teachers. Most of them believed that even though the curriculum studies modules supported them on the skills and knowledge to teach the students in the schools, more time should have been dedicated to teach and familiarise them with the concepts. It was also noted that the mathematics content curriculum followed in the schools was not stressed in the modules.

CONCLUSIONS

The student teachers were dissatisfied with the mathematics content modules taught to them as the content needed in the school mathematics curriculum was lacking in their university curriculum and that they do not get prepared adequately to become senior secondary school mathematics teachers. This calls for a more relevant content to be taught to the emerging teachers for quality mathematics education in our training courses. The themes emerged from the analysis made conclusions on connections between the Specialised Content Knowledge (SCK) and training on Knowledge of Content and Teaching (KCT) the student teachers attain as emerging teachers due to the curriculum constraints of the university. Prospective mathematics teachers need to be taught differently than mathematics majors in their university course modules for relevance, quality and purpose.

REFERENCES


THE EFFECTS OF USING GEOGEBRA ON LEARNER PERFORMANCE WHEN TEACHING LINEAR SIMULTANEOUS EQUATIONS (LSE) TO JUNIOR SECONDARY EDUCATION (JSE) LEARNERS

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ABSTRACT

This report presents the findings of an investigation of the effects of using GeoGebra to teach form 2 learners LSE. Research has indicated that the use of technology in teaching and learning Mathematics boosts results in the subject. GeoGebra as a computer application has also been used in the teaching of Mathematics. However, little if anything, is known about the extent to which it can be used as an effective means of teaching LSE to Junior Secondary Education learners. Quasi-experimentation was used in the study. The context of the experiment is form 2 learners in a Junior Secondary school in Gaborone - Botswana.

Key words: linear simultaneous equations, mathematics, GeoGebra, Botswana, instructions

INTRODUCTION

Mathematics is recognized internationally as a core subject from lower education up to our (Botswana) equivalence of senior secondary education. In Botswana it has been taught and recognised as a core subject from a long time back. However, it has also been realised that it is generally a subject in which less products, especially those with good marks in the subject are produced annually. Owing to this, the Revised National Policy on Education (RNPE) of 1994 made some recommendations concerning the introduction of technology in schools. REC. 42 [para. 5.10.12] recommends that all senior secondary school teachers should acquire computer literacy and the schools should be allocated enough computers to enable all students to develop computer skills.

Mathematics in public schools in Botswana is a compulsory subject from primary all the way to senior secondary schools and it is taken as a gate keeper (Garegae & Moalosi 2011). They decry the fact that it is generally a failed subject in both primary and secondary schools therefore it needs a strategy to enable teachers and learners to manage it well, where it is hoped teachers will effectively pass it on to learners. Further on Garegae and Moalosi (2011) state that Botswana in the Trends in International Mathematics and Science Study (TIMSS) of 2003 showed that

“Botswana obtained position 42 out of 45 countries in Mathematics also stating that TIMSS 2003 results also revealed that Botswana was two standard deviations below Singapore and one standard deviation below the international mean. The TIMSS 2007 Mathematics average
was 10% lower than the TIMSS 2003 average. These reports suggest that Mathematics education in Botswana needs some intervention to improve the status quo (pp 4).

Therefore, this suggests that a lot has to be done to improve the results of the subject.

**Significance of the Study:**
The findings will give an insight on the competency of learners in following steps using a computer to solve LSE. Learners will use GeoGebra in solving equations without having to struggle. On the other hand, teachers will have an effective teaching aid for teaching LSE. The findings will go a long way in informing policy makers and curriculum developers in determining what is appropriate for learners and how to approach solving LSE using technology and at what level.

**THEORETICAL FRAMEWORK**

The theory applied is Vygotsky’s concept of the Zone of Proximal Development (ZPD) which is based on the idea that cognitive development of a learner is defined both by what a child can do independently and by what the child can do when assisted by an adult or more competent peer.

**LITERATURE REVIEW**

Having made a deliberate decision to introduce computers and their usage in the education system, the Botswana government first availed them in schools for awareness purposes. In 2010, computer usage was introduced for instruction purposes in specific subjects at JSE level. During the same period, the Mathematics syllabus introduced some specific objectives which are being taught exclusively using spreadsheet.

The importance of ThutoNet cannot be overemphasised (Draft National Information and Communications Technology, January 2005). ThutoNet is a project that the Government of Botswana undertook to achieve sustainable ICT-driven transformation and national growth. It states that in order for Botswana to achieve the goal of a ‘knowledge-based society as outlined in vision 2016, the government must expose children to highly effective education in ICT and other subjects required for success in the digital age such as science and engineering’, hence the introduction of computers in schools.

According to Yang and Chen (2007), as cited in Chang, Lee, Chao, Wang and Chen (2010) previous research shows that media can facilitate language learning in several ways, including facilitating communication, reducing anxiety, encouraging oral discussion, developing the writing-thinking connection, nurturing social or cooperative learning, promoting egalitarian class structures, enhancing student motivation, facilitating cross-cultural awareness and improving writing skills (pp. 15).
Inter-learner cooperation must be nurtured in a learning setup to enable learners to exchange ideas. Using GeoGebra helps students to gain a better understanding of Mathematics. According to Dubinsky and Schwingendorf (2004) as quoted in Dikovic (2009) cooperative learning is the right context for a Mathematics course. Therefore, lecturing should be replaced by task-oriented interactive setup. GeoGebra provides a good opportunity for cooperative learning, that is, cooperative problem solving in small groups, or whole class interactive teaching, or individual/group student presentations (Dikovic 2009).

The use of computers as Mathematics teaching aid can improve student motivation and increase their confidence (Sivin-Kachala & Bialo 2010) as cited in (Zulnaidi & Zakaria 2012). The authors further note that many contemporary software programs can be used to help students be more responsible for their own learning through creative and interesting exploration.

In the Botswana setup there is a recommendation to use computers for Mathematics learning though there are no computers in schools. Pountney, Leinbach and Etchells (2000) talking about the use of Computer Algebra System (CAS) in the teaching and learning of Mathematics state that

The use of a CAS in Mathematics exam is not completely analogous, in fact, the CAS generally tells the Mathematics student less than the open history book may tell the history student.

The CAS merely does the numerical or symbolic calculation.

They argue that a fair assessment in the CAS environment ideally is constructed so that students with average ability can attain enough marks to pass the exam (Leinbach & Etchells 2000).

**METHODOLOGY**

The quasi experiment design was used in this study. This approach was chosen because the classes that were used were classes existing in the target school in the form 2 stream. The quasi-experiment in this case was the most suitable as the classes were already predetermined and possibly the learners themselves were not randomly chosen to constitute the classes.

A full class of 42 students was chosen and divided into two groups which were assigned the control and experimental groups. This class was chosen because at the time of the data collection, it was taught by a classmate who had not yet covered the topic on LSE. To try and balance the groups in terms of performance, the mathematics mid-year examination marks were used to select learners who constituted the groups. The marks were arranged as below in descending order and students who obtained the marks were separated such that the two top students, two second top students and so on do not go to the same group. This was done for all the forty-two students as below.

<table>
<thead>
<tr>
<th>Mid-year Examination Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>87.3</td>
</tr>
<tr>
<td>67.9</td>
</tr>
</tbody>
</table>

Table 1: Tabulated part of students’ mid-year examination results.
All students who obtained marks that are highlighted were put in the same group ‘A’ and the remaining ones in another group ‘B’. Since now there were only two groups to decide which group takes which approach a simple process was used. Two pieces of paper marked with the groups written on them were stirred in a container and randomly picked. The first group picked made the control group while the remaining one became the experimental group. Each student was given a code to use in the place of his/her name in tests.

The target group was the form 2 cohort because the objective is in the form 2 syllabus. The population was a full complement of the form 2 stream at a Junior School in Gaborone which comprised 126 students. The sample population was (n = 42). Lesson plans were prepared and used to ensure effectiveness and thorough teaching of the concepts. A worksheet in GeoGebra was also prepared for learners so they could familiarize themselves with the steps in using the application. Two common tests, the pre-test and post-test were prepared for both groups. The pre-test was administered before the treatment and the post-test after the treatment.

**FINDINGS**

Not all students wrote the test. The number of learners in the control group who wrote the post-test was one student more than those who were in the experimental group. Student T002 wrote post-tests, the pen and paper and the computer tests. Under the fourth column the student is recorded as T/C002. When recording I deliberately left out the marks of students who wrote the pre-test only but missed out on the post test because the results were not going to be of any use without a record of how they performed after the treatment. In table 1 below the columns with the titles Pre-test (%) and Post-test (%) are marks in percentage for students for the pre-test and post-test respectively. In table 2 there are results for the statements seeking opinions about the usefulness of computers as viewed by learners in the experimental group.

*Table 2: Codes and marks (pre and post-tests) for students who took part in the study*

<table>
<thead>
<tr>
<th>Student Code</th>
<th>Pre-test (%)</th>
<th>Post-test (%)</th>
<th>Student Code</th>
<th>Pre-test (%)</th>
<th>Post-test (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T001</td>
<td>0</td>
<td>100</td>
<td>T/C002</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>T002</td>
<td>30</td>
<td>100</td>
<td>C001</td>
<td>0</td>
<td>75</td>
</tr>
</tbody>
</table>


Table 3: Responses of the experimental group for the qualitative questions

<table>
<thead>
<tr>
<th>STATEMENT</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>I like using a computer to solve Simultaneous Equations</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>(Tick your response)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GeoGebra helped me to understand solving Simultaneous Equations</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>(Tick your response)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CONCLUSION

This study gave an idea of the appropriateness of using computers in the teaching and learning of mathematics. The difference in the means of the two groups suggests that education authorities need to seriously step up efforts to provide computers in schools and train teachers on their usage. I am in no doubt that a well-equipped school with fully guided teachers can turn around the not so pleasing results of mathematics in public schools.

Summary

Computer application in the teaching and learning of mathematics has been seen to be of vital importance the world over. Technology is effective in focusing student thinking. In dealing with some complex mathematics problems, more often students tend to lose focus with their concentration level diminishing due to additional cognitive load. Research has shown that technology has been very effective and useful in confining their thinking for longer periods in the problem at hand and GeoGebra is no exception. The main aim of this study was to explore the effects of GeoGebra in
teaching learners LSE, to establish if they are able to follow the procedures which lead to them garnering an appreciation of its purpose and value. The theory in mind was Vygotsky’s concept of ZPD operating alongside constructivism.

The literature that was reviewed was pro computer usage, with just a bit of it revealing some demerits about technology. The quasi-experiment was used in the study where the population was form two learners in a Junior School in Gaborone. The sampled class was divided into the control and experimental groups and were taught LSE through the traditional and computer approaches respectively. Pre-tests and post-tests were administered the results for which were analysed. The analysis centred mainly on scores obtained by both the control and experimental groups on the post-test which sought to compare their mean marks.

REFERENCES


PRE-SERVICE PRIMARY TEACHERS’ MATHEMATICAL KNOWLEDGE: AN EXPLORATORY STUDY
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1University of Witwatersrand; 2OLICO Mathematics Education
Lynn.Bowie@mweb.co.za

BACKGROUND

Primary teachers’ mathematical knowledge remains an issue of broad concern in South Africa and internationally. Most of the research on this issue in South Africa has been focused on in-service primary teachers, and particularly teachers at Intermediate Phase level (e.g. Carnoy & Chisholm, 2008; Taylor, 2011; Venkat & Spaull, 2015). A key convergence from the analyses in these studies has been the finding of substantial gaps in upper primary teachers’ mathematical knowledge. Additionally, teacher performance on items requiring reasoning beyond the purely procedural consistently show low results, and in addition to this content areas underpinned by a multiplicative structure were accompanied by low facility as well.

Predictably, in this context of concern, attention turns towards pre-service teacher education and its role in supporting the growth of prospective teachers’ mathematical knowledge. This attention rests on two assumptions – both of which have backing in the research literature: firstly, that improving teachers’ mathematical knowledge is important for building the possibility of more coherent and connected teaching; and second, that pre-service teacher education is a key lever for changing the quality of mathematics teaching in schools (Ma, 1999). There is, however, a gap in the research base accompanying this turn, with limited data on the kinds of mathematical knowledge displayed by pre-service teachers. One study that did examine this, the Initial Teacher Education Research Project (ITERP) study, indicated substantial differences in the nature and level of the mathematics covered across five different pre-service primary teacher education programmes in South Africa, as well as differences in the time allocations for mathematical study across the programmes (Bowie & Reed, 2016). However, little information is available on outcomes of such relating to the nature of pre-service teachers’ mathematical knowledge - the issue in focus in this paper.

The Primary Teacher Education project (PrimTED) was set up in response to the ITERP study findings. In PrimTED those involved in pre-service education of primary mathematics teachers at different South African universities are collaborating on a research and development project aimed at improving pre-service teacher education. The work is aimed at establishing a shared understanding of appropriate standards and curricula for pre-service primary mathematics teachers and quality materials to support these. One strand of this project has focused on assessing pre-service primary teachers’ mathematical knowledge. In this paper, we outline the instrument used to assess pre-
service teachers’ mathematical knowledge, and share the outcomes from initial exploratory administrations of this instrument across participating institutions. Driving our initial interest in this dataset are the following key questions:
- What can be said about the nature of first- and fourth-year B Ed pre-service primary teachers’ mathematical knowledge from their assessment responses?
- What kinds of differences are seen between the first- and fourth-year pre-service teachers’ mathematical knowledge?

Assessment instrument development & study design

An assessment instrument developed for the ITERP study, drawing on a range of research sources, was extended in key ways for use in the PrimTEd study. Specifically, there was attunement towards a more strongly developmental orientation: moving beyond assessments that simply indicated what participants could do or not do towards providing insights into the kinds of mathematical competences revealed. This led to an assessment incorporating lower and higher cognitive demand items across several topic strands, with the balance of items broadly reflecting the distributions of topics in the primary curriculum. Further, while the ITERP study had focused on the Intermediate Phase (IP), the PrimTEd study encompasses Intermediate and Foundation Phase (FP) trainees. This led to further categorizations of items on the basis of whether they related to FP or IP.

An initial version of the test was administered in the second half of 2017 to 4th year B Ed students at four institutions. This test consisted of 50 multiple choice or short answer questions administered in an online environment. On the basis of the analysis of the 2017 data, amendments were made to the test to replace or change five items that did not perform well. There were 45 items that remained unchanged from 2017 in the 2018 version of the test. The revised version was administered in the first half of 2018 to 1177 1st year B Ed students across 7 institutions. Over the 2017 – 2018 period, there were three institutions in which both a 4th year and 1st year cohort were tested. The results from these students based on the 45 items that were identical across the 2017 and 2018 tests are considered in this paper. Table 1 below indicates the number of items in each of the categories for the 45 common items that were considered in this study. In the marking, each item was equally weighted.

<table>
<thead>
<tr>
<th>Content area</th>
<th>Whole number and operations on whole numbers</th>
<th>Rational numbers</th>
<th>Patterns, functions and algebra</th>
<th>Geometry</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11</td>
<td>17</td>
<td>6</td>
<td>4</td>
<td>7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task type</th>
<th>Lower cognitive demand</th>
<th>Higher cognitive demand</th>
<th>Pedagogical focus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24</td>
<td>19</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Phase</th>
<th>Foundation Phase related content</th>
<th>Intermediate Phase related content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17</td>
<td>28</td>
</tr>
</tbody>
</table>

Table 1: Distribution of marks per category for 45 common items considered in this paper
Analysis and results

We considered the facility value for each item. As each item in the test was equally weighted, we used an average of the facility values of the items in each category to get a facility value for the category. We first present the average results across the five content strands for each of the groups of students (table 2) and then across the task type and Phase (table 3).

University A and B provided data about whether the student teachers were studying the BEd for Foundation Phase or Intermediate Phase and so we provide the data for each of those groups separately. University C did not provide this information.

<table>
<thead>
<tr>
<th>Broad Maths Content Area</th>
<th>Whole number and operations</th>
<th>Rational number</th>
<th>Patterns, functions, algebra</th>
<th>Geometry</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>University A Foundation Phase students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>facility for 1st yrs (n = 79)</td>
<td>0.57</td>
<td>0.67</td>
<td>0.45</td>
<td>0.63</td>
<td>0.75</td>
</tr>
<tr>
<td>facility for 4th yrs (n = 66)</td>
<td>0.62</td>
<td>0.67</td>
<td>0.56</td>
<td>0.58</td>
<td>0.81</td>
</tr>
<tr>
<td>University A Intermediate Phase students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>facility for 1st yrs (n = 102)</td>
<td>0.56</td>
<td>0.65</td>
<td>0.45</td>
<td>0.63</td>
<td>0.72</td>
</tr>
<tr>
<td>facility for 4th yrs (n = 66)</td>
<td>0.62</td>
<td>0.67</td>
<td>0.56</td>
<td>0.58</td>
<td>0.81</td>
</tr>
<tr>
<td>University B Foundation Phase students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>facility for 1st yrs (n = 117)</td>
<td>0.54</td>
<td>0.58</td>
<td>0.36</td>
<td>0.55</td>
<td>0.74</td>
</tr>
<tr>
<td>facility for 4th yrs (n = 68)</td>
<td>0.46</td>
<td>0.52</td>
<td>0.36</td>
<td>0.42</td>
<td>0.67</td>
</tr>
<tr>
<td>University B Intermediate Phase students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>facility for 1st yrs (n = 120)</td>
<td>0.54</td>
<td>0.59</td>
<td>0.38</td>
<td>0.57</td>
<td>0.70</td>
</tr>
<tr>
<td>facility for 4th yrs (n = 79)</td>
<td>0.52</td>
<td>0.59</td>
<td>0.44</td>
<td>0.52</td>
<td>0.70</td>
</tr>
<tr>
<td>University C Foundation and Intermediate phase students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>facility for 1st yrs (n = 70)</td>
<td>0.43</td>
<td>0.49</td>
<td>0.31</td>
<td>0.42</td>
<td>0.60</td>
</tr>
<tr>
<td>facility for 4th yrs (n = 45)</td>
<td>0.48</td>
<td>0.52</td>
<td>0.43</td>
<td>0.43</td>
<td>0.63</td>
</tr>
</tbody>
</table>

Table 2: Performance of 1st and 4th year student teachers analysed by overall score and score for questions in each mathematics content area.

From table 2 we note that the pattern of results shows broadly similar facilities across the 1st and 4th year cohorts. Mirroring earlier findings, facility on rational number was, in all instances, lower than in the other topic areas. At university A and B, where Foundation and Intermediate Phase student teachers were demarcated there were few differences in performance between these groups.

Table 3 provides a more nuanced insight into the differences in Y1 and Y4: in line with the observations from Table 2, across the higher cognitive demand items, facilities are similar for the two cohorts. The 4th year candidates do, however, perform a little better on the lower cognitive demand items.
Table 3: Performance of 1st and 4th year student teachers analysed by score for questions grouped according to task type and the Phase the content relates to.

One area, in one university where there is a clear difference across the years, is on the pedagogic items in University A; it would be interesting to interrogate that University’s curriculum to see if that helps account for this. However, the pedagogy category contained only two questions as many of the 2017 pedagogy items had performed poorly and so were amended so this result needs to be treated with caution.

Discussion
While this dataset is quasi-longitudinal rather than longitudinal, it might be expected that the students would have gained in their mathematical knowledge after 4 years of a BEd, but this data suggests otherwise. Of particular concern is the relatively poor performance of 4th year student teachers on higher cognitive demand items. This would suggest that many fourth-year student teachers have not made significant strides towards the profound understanding of fundamental mathematics that Ma (1999) suggests is important for teaching.
Both the test and this analysis represents an initial exploration of the issues and flags areas for further research. In particular there is a need to investigate the kind of assessments and results currently in use in BEd courses across institutions and compare these to the kind of assessments emerging from the PrimTed process. There is also a need to reflect back on the links between the results of these assessments and the implications for the courses currently on offer to prospective primary mathematics teachers.

References
A METACOGNITIVE APPROACH TO CATCHING-UP HIGH SCHOOL LEARNERS’ ACQUIRED LEARNING DEFICITS IN MATHEMATICS

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ABSTRACT
South Africa’s problems of low participation and performance in Mathematics are persistent despite 25 years of reform, prioritized budget and redistributed funding to redress imbalances of the past. In 2012, a donor-funded Maths enrichment programme for 50 Grade 10 learners from ten high schools in rural Mpumalanga found a way to combat this challenge. A baseline diagnostic assessment revealed that all 50 learners were functioning between Grade 2 and Grade 6 levels in Maths. Learners underwent an intervention designed to metacognitively activate them through: diagnostic assessment as learning, explicit formative feedback, personalized remediation, interpreted learning pathways and reflective activities. Achievement was measured on baseline, class and summative tests resulting in a cohort average increase of 42 percentage points on the same diagnostic administered pre- and post-intervention. The findings show that: acquired learning deficits in Maths can be overcome using a metacognitive approach; these learners caught up between three to six grade-levels within one year using this approach; Grade 10 is not too late to fix learning deficits with a targeted, metacognitive approach.

Keywords: Mathematics catch-up; diagnostic assessment; metacognitive activation; reflective learning.

INTRODUCTION

In 2017 less than 9% of all Grade 12 learners passed Mathematics at 50% or more (DBE, 2017). This is not surprising considering that in 2014, when most of these learners were in Grade 9, only 3% of all learners passed Maths at this level (DBE, 2014). Spaull (2013) warned of growing learning gaps among disadvantaged learners which would cause them to fall so far behind by high school that remediation would be impossible. Spaull and Kotze (2015) call these learning gaps from early years “insurmountable learning deficits”. Their findings confirm the learning gap between the poorest 60% of learners and the wealthiest 20% in South Africa is approximately three grade-levels by Grade 3 growing to four grade-levels by Grade 9.

In February 2012 Uplands Outreach launched a donor-funded Maths programme called Learners for Excellence (L4E). Focused on making an impact in the impoverished and poor-performing circuit of Insikazi, the aim was to increase both numbers of learners passing Maths as well as the quality of
results. Fifty Grade 10 learners attended weekly Saturday Maths enrichment sessions over three years. A baseline assessment produced disappointing results revealing extensive and deep learning deficits. This necessitated a shift in the planned L4E programme. The project evaluator, a Maths consultant, facilitated an additional hour-long weekly ‘catch-up’ class. This class focused the learners on using their own diagnostic data to identify their learning needs and, through a metacognitive approach, to ‘make up’ acquired learning deficits and fast-track learners to actual grade-level expectations of performance in the shortest possible time.

CONCEPTUAL FRAMEWORK

The intervention approach was characterised by:

- **diagnostic assessment with explicit formative feedback**
  In line with “assessment as learning” approaches (Earl, 2003; Wiliam, 2012), diagnostic results and formative feedback were shared with learners. Class activities were analysed to understand personal misconceptions and learning challenges revealed by errors. Self-, peer- and group assessment activities were embedded in contact sessions.

- **interpreted learning pathways (called conceptual threads)**
  Inspired by Charles’ “Big Ideas” (2005) and the learning trajectories of Clements and Sarama (2004) and Confrey (2006), achievements on concepts along conceptual threads (Numbers, Fractions, Patterns & Algebra, Space & Shape, Data Handling and Problem Solving) were shared with learners to facilitate their understanding of relationships between concepts and for building the connections between new and existing, secure knowledge.

- **personalised remediation**
  Learners used feedback of their grade–level of mastery on the specific concepts to guide their participation in the grade-level activities available in the weekly contact sessions. Daily homework was set for each weekday in-between the Saturday sessions.

- **reflective activities**
  Classroom activities and marked homework were analysed by the learners through guided self-reflective activities to develop their metacognitive skills. Learners estimated predicted performance on tasks (Hattie’s self-reported grades, 2009), analysed their results, compared results and predictions, identified strengths, weaknesses, discussed challenges and opportunities in personally maintained reflective journals.

METHODOLOGY

While the L4E programme ran for three years from February 2012 to October 2014, the study only focused on the ‘catch-up’ intervention which was completed before June 2013. At the time, data was collected to inform the direction of teaching and learning and was not intended for research purposes. This study only began in 2015 after L4E learners had already matriculated. A mixed methods approach with narrative and quasi-experimental components provided qualitative data and
quantitative data for the study. The sample was composed of 50 learners (five learners from each of ten schools) who were not randomly selected.

Learners wrote an early iteration of the Reflective Learning diagnostic as a baseline and summative measure. The questions were designed to test the level of mastery (Grade 3, Grade 6 or Grade 9) irrespective of a learner’s actual grade, of specific mathematical concepts (referred to as conceptual landmarks) on identified mathematical learning pathways or trajectories (referred to as conceptual threads). The diagnostic was designed to reveal fundamental errors, conceptual difficulties, common misconceptions as well as issues featured in published research. This diagnostic design has subsequently been piloted with thousands of learners in a wide variety of school environments across South Africa and is generating reliable results which are currently informing seven independent intervention pilots. After 26 weekly one-hour contact sessions, the learners wrote the diagnostic again under same conditions but the summative test was split into two parts. This was because formative assessment activities in the classroom had already shown that little progress had been made in the more resistant conceptual threads of Fractions and Problem Solving, so it was decided to hold these over until 2013.

Baseline test scores and summative test scores were compared for the cohort and individual learners including Grade levels of mastery (Grades 3, 6 or 9) provided by the diagnostic feedback. Data was subjected to statistical analysis to clarify distribution and a t-test was carried out for paired difference to calculate significance of the difference between the start and the end of the intervention.

FINDINGS

Pre-intervention baseline achievement ranged from 10% to 48% with a cohort average of 23.8%. Five learners were not yet at Grade 3 mastery level. Thirty-eight learners performed between Grade 3 and Grade 6 levels with only seven learners between Grade 6 and Grade 9. No learners were at Grade 9 level.

Post-intervention summative achievement ranged from 32% to 93% with a cohort average of 65.5%. Thirty-four learners performed between Grade 6 and Grade 9 levels with only one learner remaining just below Grade 6 level. Fifteen learners were achieving at Grade 9 level and above.

The t-test confirmed 99.9% confidence in statistical significance.

CONCLUSION

The L4E intervention ‘made up’ acquired learning deficits and ‘caught up’ these learners in a short period of time. These 50 learners progressed by at least three to six grade levels of pre-FET Maths with some learners making even larger gains in only a one year period despite the limited contact time. With an overall average improvement of 42 percentage points, by the end of the intervention
all learners were either approaching, meeting or exceeding grade-level achievement for the end of Senior Phase. The study shows that learning deficits from early grades are not necessarily insurmountable and that Grade 10 is not too late for learners to catch up and achieve in Mathematics using diagnostic data, targeted remediation and a metacognitive approach to intervention.

REFERENCES


THE POTENTIAL OF METACOGNITIVE ACTIVATION TO IMPROVE LEARNING IN MATHEMATICS

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1Reflective Learning; 2School of Education, University of the Witwatersrand
E-mail Address: traceybutchart@gmail.com

ABSTRACT
In 2012, a donor-funded Maths programme for 50 Grade 10 learners from ten high schools in rural Mpumalanga used a metacognitive approach to catch up learners who were revealed by baseline assessment to be three to eight years behind their actual grade in Maths. Learners underwent an intervention designed to develop metacognitive skills through: diagnostic assessment as learning, explicit formative feedback, personalised remediation, interpreted learning pathways and reflective activities. While Maths achievement was measured on baseline, class and summative tests, learners’ estimations of predicted performance, their analyses of strengths, weaknesses, challenges and opportunities and personal journal entries were used to provide evidence of their metacognitive skills development. The ‘catch-up’ intervention was successful with all learners advancing by between three and six grade-levels within one school year. Over the same period, the learners’ ability to estimate their predicted performance improved through an identifiable point referred to as ‘metacognitive activation’. Learners showed improvement in communicating their meta-learning suggesting progress in metacognitive skills. While further research is required, a metacognitive approach in the Maths classroom may offer more than just fast-tracking the catching up of learning but also foster independent, successful learning behaviours for post-school success. Keywords: Mathematics catch-up; metacognitive activation; reflective learning.

INTRODUCTION
It is disappointing each year when the Grade 12 NSC Maths results are released in South Africa and we are reminded that the majority of learners do not study Maths. Those that do, struggle to achieve. In 2017 only 22% of the 49% of matric learners doing Mathematics passed it at 50% or more (DBE, 2017). This cohort’s difficulties were already documented three years earlier when only 3% of Grade 9 learners passed at 50% or more in the Maths ANA (DBE, 2014). Finding a scalable solution to remediating what Spaull and Kotze (2015) referred to as “insurmountable learning deficits” remains urgent. A programme run by Uplands Outreach from 2012 to 2015 provides an alternative approach to the extra classes, group lectures and past-paper practice activities characterising most interventions. Called Learners for Excellence (L4E), it involved 50 learners from 10 high schools in the under-performing circuit of Insikazi, Mpumalanga. When the baseline assessment revealed success-
inhibiting learning deficits, a catch-up intervention was implemented. A metacognitive approach was chosen to fast-track learners’ catch-up as quickly as possible.

CONCEPTUAL FRAMEWORK

The metacognitive approach depended on:
• diagnostic assessment with explicit formative feedback
  Assessment as learning strategies of Earl (2003) ensured that all results and feedback were shared with learners. Self-, peer- and group assessment activities embedded in contact sessions promoted the value of learning from mistakes and taking responsibility for necessary corrective action.
• interpreted learning pathways (called conceptual threads)
  Inspired by Charles’ “Big Ideas” (2005) and the learning trajectories of Confrey (2006), concepts were contextualised along conceptual threads (Numbers, Fractions, Patterns & Algebra, Space & Shape, Data Handling and Problem Solving) in order to facilitate learners’ understanding of relationships between concepts and to foster building the connections between new and existing, secure knowledge.
• personalised remediation
  Learners used feedback of their grade-level mastery of specific concepts to guide their own participation in the grade-level activities available in the weekly contact sessions. Daily homework was set for each weekday in-between Saturday sessions. This was to encourage learners to make positive choices and take control of their learning.
• reflective activities
  Classroom exercises, marked homework and tests were analysed by learners through guided self-reflective activities with further reflections captured through their weekly journal writing.

I work with Flavell’s definition of metacognition (1971; 1976) as ‘metacognitive knowledge’: knowing what you know and what you don’t know, understanding how you learn, knowing about strategies, what strategies to use and when to use them to make understanding, being aware of your strengths and weaknesses; and ‘metacognitive expertise’: managing and improving your learning through planning, implementing, monitoring and evaluating learning strategies with self-reflection to increase cognition. I have used Kruger and Dunning’s findings (1999) as indicators of metacognitive progress. They found that metacognitively unaware students over-estimate their capabilities and the realisation of their limitations results in students under-estimating themselves before they are able to accurately predict their performance. I have used the term ‘metacognitive activation’ to describe that turning point of becoming metacognitively aware.

METHODOLOGY

This research study was undertaken in 2015 after the three-year L4E programme had ended. Mixed methods with narrative and quasi-experimental components providing qualitative data and
quantitative data collected between February 2012 and June 2013. The sample of 50 learners were selected by the Insikazi circuit manager and the schools’ teachers. In personal reflective activities in each weekly session, learners estimated their predicted performances, classified their Maths proficiency on specific concepts (as novice, apprentice or practitioner), identified, described and discussed their strengths and weaknesses with respect to class, homework and test activities, suggested strategies for improvement and progress, analysed their performance for errors, challenges and remediation needs. Learners maintained personal journals. Learners’ responses were categorized on a specifically constructed rubric defining metacognitive skill levels, where 0 indicated metacognitively unaware and unskilled, 1 indicated metacognitively activated but unskilled, 2 indicated metacognitively aware with growing skills and 3 indicated metacognitively advanced. Rubric level descriptors defined evidence of performance on each criterion. A new measuring tool was devised because: the retrospective study precluded interviews or think-alouds of Garner (1988); the dependency on general questions without a specific Maths focus detracted from existing tools such as LASSI (Weinstein, Zimmerman & Palmer, 1988), MSLQ, (Pintrich, Smith, Garcia & McKeachie, 1993), MAI (Schraw and Dennison, 1994), and KMA (Everson and Tobias, 1998); and there was a need to compare learners’ metacognitive skills over time.

**FINDINGS**

The catch-up intervention resulted in a 42% average improvement between pre-intervention and post-intervention scores on the same diagnostic test. All L4E learners caught up between three and six grade-levels in one year. The metacognitive measures improved faster. The percentage of learners over-estimating their performance dropped from 94% to 7% in the first month of intervention while those under-estimating themselves increased from 6% to 65%. The number of learners estimating within a range of 10% or within the same proficiency classification (novice, apprentice or practitioner) as their achievement grew to 28% from zero. Learners’ reflective writing as assessed on the devised rubric, showed increased metacognitive skill levels with all learners identified as metacognitively activated after the intervention.

**CONCLUSION**

Based on Kruger and Dunning’s work (which connects progression from metacognitive unawareness to awareness with progression from over-estimating to under-estimating capabilities) these L4E learners showed improvement in metacognitive skills. The clearly identifiable point when learners shift from over-estimating to under-estimating appears to be the marker of metacognitive activation of learners even if they have not yet acquired metacognitive skills. While the retrospective nature of this study may have compromised metacognitive measures (as full access to learners’ written reflections was not possible and the variety of reflective activities necessitated the rubric to compare them), a metacognitive approach offers potential for improving not only Maths learning. This view is strengthened by the facts that 98% of these 50 learners passed Grade 12, with 63% of these achieving
above 50%; and that in 2015, the 58% who were able to access tertiary study achieved a 100% pass rate.

REFERENCES


AN ANALYSIS OF HOW THE USE OF GEOBOARDS AS VISUALISATION TOOLS CAN BE UTILIZED IN THE TEACHING OF QUADRILATERALS: A NAMIBIAN CASE STUDY.

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ABSTRACT
This paper which is based on an ongoing study, reports on aspects of using a geoboard in visualisation processes. Three purposively selected grade 7 teachers participated in a 3-months intervention program on how to use a geoboard in teaching and learning mathematics. Teachers in this study alluded to the dynamism of geoboards, improved classroom interaction, visuality of the geoboard and some challenges they faced in using this visual tool. We conclude that while teachers may experience some challenges with the geoboard, its use presents more benefits than limitations and encourage teachers to use the geoboard as a visualisation tool when teaching quadrilaterals to grade 7 learners.

INTRODUCTION

The Namibian national curriculum for basic education compels mathematics teachers to be “creative and innovative to produce their own teaching and learning materials linked to practice” (Namibia. Ministry of Education, [ME], 2010, p. 6). One of the primary reasons why mathematics teachers should employ concrete objects is to help learners to relate what they are seeing, touching and experiencing in the classroom to real life objects and experiences (Owens, 2003). However, despite the call from the Ministry of Education for teachers to make use of teaching and learning aids and materials, many teachers still find it difficult to create and make use of these teaching aids and materials. Miranda and Adler (2010) observed, “Namibia is one of the many African countries, in which the use of manipulatives in mathematics classrooms is not a common practice” (p. 17).

Our experiences in teaching has shown how learners struggle with issues related to the correct description of the properties of quadrilaterals such as those of squares, rectangles, parallelograms, rhombus, trapeziums and kites. This could be attributed to the absence or limited use of concrete teaching aids, visuals and manipulatives, such as the geoboard. This paper focuses on how a geoboard can be used as a visualization tool by teachers for the purpose of developing and enhancing conceptual understanding of the properties of quadrilaterals. Thus, the following research questions frame this study: How can geoboards be utilized as visualisation tools by teachers in the teaching of the properties of quadrilaterals in grade 7 classes as a result of participating in an intervention programme? What are the teachers’ experiences of using geoboards as a visualisation tool in teaching the properties of quadrilaterals as a result of participating in this intervention programme?
The Geoboard

A geoboard is a physical manipulative tool that is made out of a flat piece of wood with small nails hammered in an arrangement of points that are in a pattern of repeated squares (Coleman, 1978). It was traditionally designed as a pedagogical device to be used for the teaching and learning of geometrical shapes by placing rubber bands around the nails to form different shapes (Scandrett, 2008). It is a simple but effective instrument that can be easily constructed from local materials and can be used to teach various mathematics topics. The concrete experiences developed in geoboards enable learners to relate the abstract to the real world.

CONCEPTUAL FRAMEWORK

Visualisation is described as both a product and a process of creation, interpretation and reflection upon pictures and images (Arcavi, 2003). Visualisation can refer to a mental process, visual thinking or reasoning that employs visual imagery in the solution of problems (Makina, 2010).

Visualisation processes involve the use of visual imagery. Makina (2010) describe working with visual imagery as the ability to form mental representations of the appearances of objects and to manipulate these representations in the mind. Therefore, the use of geoboards as a visualisation tool can easily be aided by visual imagery such as concrete pictorial and dynamic images. Presmeg (1986) asserts that learners can think in pictures without any linguistic support. Thus, I see the geoboard as a visualisation tool that can enable learners to think in pictures.

Teaching for conceptual understanding is directly related to the effective use of concrete objects and the power of visual representations (Makina, 2010). However, the use of any concrete and visual representation is only a tool; the final destination is conceptual understanding. Thus, the embedding of visualisation processes in geoboards opens opportunities for the learning of new knowledge, and this may develop the conceptual understanding of basic shapes in learners.

THEORETICAL FRAMEWORK

This study is positioned within the constructivist theoretical framework that holds that teaching and learning is a constructive process where learners build an internal representation of knowledge through a personal interpretation of experience (Gupta, 2011). It is a theory of learning that states that individuals construct their own new understandings on the basis of an interaction between what they already know and believe against the ideas and knowledge that they come into contact with (Piaget, 1967).

METHODOLOGY

This research was undergirded by the interpretive paradigm. The research used a case study approach. The case involved three purposively selected grade 7 mathematics teachers in the Opuwo...
circuit of the Kunene region in Namibia. The teachers are identified in this study with their pseudonyms, Mr. Tame, Mrs Ntake and Ms. Katu. These three teachers participated in a 3-months intervention program on how to use a geoboard in teaching and learning mathematics. After the intervention, they then taught two lessons each that were video recorded. Data was collected through lesson observations and interviews.

FINDINGS

This section reports some of the findings that have emerged from interviews and lesson observations. For the purposes of this paper, we will briefly report on some emerging themes from our observations and interviews and these are dynamism of geoboards, classroom interaction, visuality elements and some challenges.

**Dynamic elements of Geoboards**

Teachers alluded to the dynamism that a geoboard affords to the teaching of mathematics as a visual tool especially in forming and transforming geometric shapes. The teachers had this to say

> If you compare the two, the Geoboard and the chalkboard, you see on the chalkboard it is somehow a bit difficult because you have to draw whether it is a square or a rectangle. Then if there’s a mistake you have to rub again and restart. (Mr. Tame)

> With the Geoboard it was very easy because you just take the rubber bands and you can adjust them even learners could adjust them the way they feel like. I mean extend the corners of a square or to put them inside to form a rhombus. (Mrs. Ntake)

> The learner turned around the geoboard and then counted the pins at the new bottom. Instead of four pins now she had six, of the same trapezium. Although only the position was turned around it remained a trapezium yet the learner looked at it from a different angle. (Ms. Katu)

Mr. Tame pointed out that the geoboard does not need cleaning but adjustment of rubber bands if one is correcting a mistake or improving the figure constructed. Both Mrs Ntake and Mr. Tame noted the dynamic element of the geoboard in that quadrilaterals can be transformed and moved by placing the elastic bands in different positions. Teachers concurred that construction and manipulation of quadrilaterals on geoboards was a lot easier as compared to doing it on the chalkboard. Ms. Katu cited a scenario from her lesson where some learners after constructing a trapezium turned the geoboard and an interesting discussion ensured. Such a dynamic element only occurs when movable manipulatives such as a geoboard are used.

**Geoboard and classroom interaction**

In all the teachers’ lessons, the geoboard brought about excitement and increased participation during teaching. It improved participation, livened up the class and everybody was attentive.
Most of our learners are used to a chalkboard but when I introduced a geoboard, they were so excited. Everyone was interested; everyone was willing to take part. They were free to do whatever they had to do there. The Geoboard was something new to them, so the participation was so good because everyone wanted to interact with the Geoboard. I had calm them down, because everyone wanted to say or do something. (Mr. Tame)

Learners were given opportunity to make their own constructions in groups. They thus explore the geometric figures on their own. (Mrs. Ntate)

Learners were sharing the Geoboards in groups and every one was interested in doing something, in constructing something, everybody wanted to touch here and there. Therefore, everybody was actively participating although not all the members of the group knew exactly what they were constructing. They were so eager to do and finish the individual activity. Everybody was eager to do it on his or her own. (Ms. Katu)

The geoboard helped to cater for diverse learners, the shy and not so shy ones, the average and the fast learners in the teachers’ classes. It can be argued that was because the learners worked in groups. The teachers’ use of this visual tool brought variety and innovation to learning in these teachers’ classrooms.

**Visual Representation**

The geoboard was seen as a useful way to show the visual representation of geometric concepts in a cheaper and yet not so common way in these classes.

I asked them why they said they have four equal parts. They visually proved it by counting the pins to show that all the sides had four pins. Moreover, even when it came to the line of symmetry, they could use four rubber bands to show that a square has four lines of symmetry proving it using the rubber bands on the Geoboard. (Mr. Tame)

Now when they looked at the trapezium turned around, it was upside down in their eyes. It was now turned into a different shape for some, but in reality, it was still the same trapezium. It was interesting coz the learners looked at it from a different perspective. (Ms. Katu)

Ms Katu identified the flexible nature of a geoboard. An example is the turning and re-orientation of the geoboard.

**Challenges with the geoboard**

Teachers in this study experienced some challenges with the geoboard. They shared these during the interviews.

Ms. Katu had challenges relating to the size of the geoboard in relation to her class size. She suggested that a bigger geoboard would be needed to increase visibility from all corners of the classroom.

I translated the idea from the Geoboard on to the chalkboard simply because this Geoboard is a bit small for the class. The learners who were seated at the back could not see clearly the structure that I had constructed for them. The availability of enough Geoboards played a major role within my lesson. The sizes, spaces and distribution of pins might have an effect. Some were made with the smallest pins there, and it affected the shape. If we can have a very big one just for the whole class then everybody can use. Bigger rubber bands will be required for demonstration purposes. (Ms. Katu)

Some geometric concepts were not so easy and apparent to demonstrate on the geoboard. Mr. Tame and Mrs Ntate gave example of lines of symmetry.
Mrs Ntake suggested that using pins and rubber bands for illustrating symmetry on the geoboard would work well when an odd number of pins is used. This is because of the existence of a clear set of pins in the middle. They noted that this was not the case when an even number of pins on the side of a shape were used.

SUMMARY AND CONCLUSION

Teachers in this study concurred that using a geoboard was a worthwhile endeavour that positively affected the teaching and learning of quadrilaterals in their classes. Using a geoboard as a visual tool assisted learners to see and experience first-hand, the mathematics concepts related to geometry of quadrilaterals. The geoboard offered increased opportunities to debate and discuss what they could visualize. Learners were also afforded opportunities to change and adjust with ease, figures they had originally constructed. The use of the geoboard thus to some extent helped learners to physically and mentally build conceptual understanding of quadrilaterals and their properties. The dynamic aspect of the geoboard helps learners to ‘imagine what it would look like’ if they moved a shape from one position to another, or manipulate shapes to form other different shapes.

With the results we have so far, we conclude that while teachers may experience some challenges with the geoboard, its use presents more benefits than limitations. We encourage teachers to use the geoboard as a visualisation tool when teaching quadrilaterals to grade 7 learners.
INVESTIGATING HOW THE USE OF VISUAL MODELS CAN ENHANCE THE TEACHING OF COMMON FRACTIONS FOR CONCEPTUAL UNDERSTANDING IN GRADE 8 LEARNERS: A NAMIBIAN CASE STUDY

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INTRODUCTION

Fractions are a compulsory key component of the mathematics school curriculum in Namibia. The mathematics education research literature is resounding in its findings that understanding common fractions is a challenging area of mathematics for learners to grasp (Bruce, Chang & Flynn, 2012). Learners of mathematics in schools seem to have difficulty retaining fraction concepts ((Pantiziara & Philippou, 2012). In Namibia, grade 8 learners are expected to be able to compare and order fractions as well as to perform the four basic operations on fractions (Namibia. Ministry of Education, 2010). Learners’ ability to understand and work with fractions is crucial. Teaching of fractions thus should be done in a way that helps learners to retain fundamental fraction concepts for current and later use. Nevertheless, most learners in this grade enter this level with inadequate preparation and prior knowledge necessary to succeed in this topic in grade 8. It is against this background that we chose to conduct a study that explores the teaching of common fractions to grade 8 learners using visual models.

VISUALISATION AND VISUAL MODELS IN MATHEMATICS TEACHING

Visual models according to Konyalioglu et al., (2011), are tools which are used to represent abstract concepts of mathematics in a constructive way which leads to the mental interpretation of an image in the mind of learners. Visual models are used to bridge the gap between understanding through concrete objects and symbolisation. The use of visual models occurs in the ambit of visualisation. Arcavi (2003) suggests a broad definition of visualisation. According to him visualisation is the ...

ability, the process and the product of creation, interpretation, use of and reflection upon pictures, images, diagrams, in our minds, on papers or with technological tools, with the purpose of depicting and communicating information thinking about and developing previously unknown ideas and advancing understanding (p. 217).

The National Council of Teachers of Mathematics (NCTM) (1989) indicates that visual models often make use of physical materials and other representations that help children develop understanding of fraction concepts. Konyalioglu et al., (2011) also articulated that visual models help in enhancing problem solving skills and can also play an important role in long term recalling. Visual models in
mathematics’ problem solving enhances comprehension and helps learners to come up with a variety of possible solution opportunities (Konyalioglu et al., 2011).

THEORETICAL FRAMEWORK

This research study locates its theoretical underpinnings in constructivism. In the constructivist theory people construct their own understanding and knowledge of the world, through experiencing things and reflecting on those experiences (Gupta, 2011). Constructivism and visualisation are linked and interconnect at developing conceptual understanding for learners. As learners construct diagrams, pictures, visual models and shapes whether on paper or in their mind, conceptual understanding is enhanced. At the heart of the broader study is a teacher intervention programme that seeks to use visual models as visualisation tools to teach the concept of common fraction in a conceptual manner that will facilitate the construction of fraction knowledge in a constructivist manner in the context of the Namibian curriculum. The fraction models that were at the core of the intervention program were: the area model, the number line model and the set model (Pantiziara & Philippou, 2012).

RESEARCH GOAL

The aim of this study is to explore how selected teachers use visual models to improve teaching common fractions for conceptual understanding to grade 8 learners as a result of participating in an intervention programme.

**Research question:**
1. What is the nature of the different visual models used by grade 8 mathematics teachers in the Khomas region of Namibia in the teaching of common fractions prior to participating in an intervention programme?
2. What is the significance of the observed visual models to the teaching and learning of fractions in grade 8?

SAMPLE AND RESEARCH PROCESS

This study is oriented in the interpretive paradigm. The study initially used a survey of all secondary school mathematics teachers in the Khomas region of Namibia. A case study of six grade 8 teachers that were selected purposively and conveniently from this region then took part in an intervention programme.

While data for the bigger study were collected through surveys, observations and interviews, only data collected through surveys and interviews is presented in this paper. The data from the survey questionnaire was analysed both quantitatively using descriptive statistics and qualitatively using emerging themes.
FINDINGS

Visual models used by teachers in Khomas Region
In this survey, 88% of the teachers in Khomas Region reported that they used some form of visual manipulatives when teaching fractions. Only 12% said they use none (see Figure 1). In this region, 22% said they use diagrams to teach fractions. The other visual strategies had less numbers of teachers using them. This was because they said diagrams could be drawn quickly on the chalkboard or white board or on paper thereby requiring relatively little time to prepare than the other visual models. ICT, which is expected to be gaining more use in this modern era, was used by only 2% (see Figure 1) of the grade 8 teachers in the Khomas Region.

![Figure 1: Types of visual models used by teachers in Khomas Region](image)

Teachers who were interviewed alluded to the importance and classroom benefits of using visual models.

*I think presentation with visual model helps learners see exactly how the fraction is represented. In mixed numbers, they see everything that you have a whole and they can clearly see that this is a full whole of a fraction and this is the part of a fraction. So I think it helps learners to visualise and see exactly what is happening. (Mr. Malele)*

*When using visual models learners find it easy and enjoyable, because these learners they like seeing instead of just hearing numbers, they are used to numbers already and some of them are scared of numbers. When they visuals models mathematics becomes more interesting than when we use numbers only, that’s what I observed. (Mr. Mose)*

Mr. Malele pointed out that a visual model presents reality and concretises learning of fractions. Mr. Mose added that visual models make learning easier and enjoyable. While the study asked about
various models that teachers used, most teachers were using very few of those manipulatives that were identified. Some teachers said they only use one.

Teaching of fractions
Teachers indicated that they used different materials to teach fraction and they used them in different ways to make learners understand the concept of fraction better. When asked about what manipulatives they use to teach fractions, some of them said

- I use paper strips and drawings to show the numerator and the denominator
- I use different manipulatives such as drawings, strips and cut different objects to form up a fraction
- I normally draw fractions in cards, cut fruits into different fractions, using readymade materials that shows fractions.
- I use geometric shapes to introduce fractional numbers, by cutting the shapes out or paper plates

They indicated that they use paper strips, drawings and other geometric shapes (as indicated in Figure 1). Nevertheless, during teaching, the teachers we observed were all using the area model. When interviewed, Mr Malele and Ms Nalo explained why he favoured this model:

The two model that I have used, area and number line, are both helpful. But I have seen that using area models is quite easier, where you just draw separate wholes and you divide them into parts as given by the fractions that makes learners to understand better compared to the number line model. Area model also connects with other previously done concepts. I realised from the feedback that learners gave me as we were looking at these things that area models is easy to use. But in my own capacity as a teacher, the area model is a bit easier because it’s easier to draw and it’s also easier to present.

(Mr. Malele)

The area model is easy and convenient to use. The area model I think that was the best one, compared to the number line. With the number line, the problem is when it comes to addition and subtraction, to find the lowest common denominator. However, with the area model, we were cutting the whole drawing. It’s like we cut it more into smaller pieces so they can see the common denominator from the cuttings. So, when we cut in those twelve equal parts of a different colour inside that area model learners, could see those parts that we drew unlike the number line where you have to put the small lines on top. Therefore, I think the area model is the best and it is user friendly. The number line is bit complicated.

(Ms Nalo)

The dominance of the area model in the observed classes was due to this model being easier to draw and use, and the ability to link area model to prior knowledge. Ms Nalo argued that the number line
model was not as easy to use as the area model when adding or subtracting fractions of different denominators. All these factors lead to the dominant use of the area model we observed in this study. Teachers surveyed alluded to the relevance of using visuals models drawn from the local environment. Some of their statements are given below:

- Teachers need to give practical example of sharing whole unit and emphasise on parts as fraction of the whole.
- One can use an orange that is peeled and divided to make learners understand better the concept of fraction.
- Illustrate by incorporating examples such as pizza or pictures of a sliced pizza.
- By make use of materials like apples, pie cut them in slices and using number of learners in the class.

The use of everyday and locally found visual materials was noted. These teachers considered the chosen examples such as pizza, apples and oranges as useful. These materials are locally found because Khomas Region is predominately urban. A few of the teachers suggested role modelling. One participant said, “Use learners themselves, arrange them in groups then ask one learners to stand and make a fraction of the whole group. While using learners in the class is plausible, one must guard against disadvantaging those who are role-playing. In addition, mathematization should be prioritised at all stages of learning.

Significance of using visual models when teaching fractions

Participating teachers indicated the importance of teaching fractions using visual models in grade 8. Some of their response were;

- It helps learners to understand the concept much better
- It enables learners to attach meaning to the concept being taught in their daily live
- It helps learners to understand the concept of fraction much better and it help them to understand the concept of fair sharing.

Teachers viewed the use of models as providing access to knowledge, understanding and meaning during the learning process. Teachers also mentioned that visual models are significant for bridging the gap between theory and the concrete of fractions. They also mention that visuals aid memory and retention of learnt materials about fractions.

- It will help learners to relate mathematics to every days life
- Learners remember better when they see as opposed to when they just hear it.
- It help the learners to see the reality of fraction, make comparisons or links
- Perception in children develop broadly when human senses are intensively involved and fraction concepts are a bit abstract because they represent quantities that are not whole. Therefore visualisation is important in the sense that it help learners to develop broadly the concept of common fraction and help learners to relate fraction to other concepts.
- It help learners to grasp the concept easily and they hardly forget it because they will have the picture in mind
Mr Mose’s experiences are highlighted below as an example of how these teachers experienced the significance of these models in their teaching.

* I gained more experience on using visuals models during this period and process. I wish maybe it could be even be part of the prescribed books that we are using in teaching. Because if it became part of the books that our learners are using it will save much of our time that we spend in drawing. I also learned that using visual is easy and it help learners to understand this topic much better. Another experience that I gained is that using visuals allows learners to be involved in their own learning because usually we used to struggle when we are teaching these fractions especially when we have to compare. The old way was very difficult for them but now that they know how to use models it also helped them even with ordering fractions. The use of visual is very easy for our learners and it made them understand the topic of common fraction in no time. *(Mr Mose)*

Mr Mose pointed out that the use of visual models helped him in his teaching in terms of saving time and effort. To him, using visual models made his teaching much easier and enhanced understanding of fraction concepts when he compared it with ‘traditional’ methods. He also suggested that the inclusion of visual models in learners’ textbooks would assist both teachers and learners during the teaching and learning of fractions.

**SUMMARY AND CONCLUSION**

Grade 8 Mathematics teachers in Khomas region who took part in this study were noted to predominantly use diagrams drawn on the chalkboard, whiteboard and/or on paper as compared to concrete objects, ICT and other visuals. Lesson observations revealed that teachers preferred the area model. This resonates with the prevalent use of diagrams mentioned above. They pointed out that the area model was easier and more convenient to use as it also linked with learners’ prior knowledge and integrated fractions with other domains of mathematics. While we acknowledge that certain visual models work best and well with certain mathematical concepts, we also encourage teachers to explore further other models other than the area model when teaching fractions to grade 8 learners.
DEVELOPING PRE-SERVICE TEACHERS’ REFLECTIVE PRACTICE AND THE KNOWLEDGE REQUIRED TO TEACH MATHEMATICS

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ABSTRACT
Reflective practice is an essential skill in the work of teaching yet not so easy to develop particularly in pre-service teachers. This paper discusses how pre-service teachers at a university in South Africa develop reflective practice as they analyse video-based lessons using a Six Lens framework that Karsenty, Acarvi and Nurick (2015) designed for guiding in-service teachers as they reflect on video-based lessons. Their preliminary reflections were analysed to determine the levels they are reflecting at. The findings show that preservice teachers start by reflecting at varying levels of the technical description level. This rises a need to develop a framework that caters for these varying levels of reflectivity. The SLF was found to be useful in guiding preservice teachers’ reflections and that they start reflecting at varying levels of technical descriptions.

INTRODUCTION
The ability to reflect is considered an essential skill for thinking productively about instruction and is regarded as predictive of how well one will be able to teach (Sherin & van Es, 2009). However being able to reflect does not come natural but develops in stages as one puts an effort to. Ward and McCotter (2004) alleges that preservice teachers often do not understand what reflection is and how to reflect, often mistaking it for description of teaching. This suggests a need for teacher educators to provide opportunities for PST to develop reflective practices and give them feedback as a way of helping them develop a decision-making schema (Griffin, 2010). According to Griffin, “if beginning teachers are not firmly and confidently grounded in pedagogy and curriculum with an effective decision-making schema based on reflective and critical thinking, the knowledge and skills gained in their training program may be quickly and easily obliterated” (p. 208).
Muir and Beswick (2007) purports that learning to reflect critically is a process that goes through three hierarchical stages

- Level 1 - technical description. Teachers describe the classroom experiences focusing mainly on the technical aspects of teaching without considering the importance of those experiences,
- Level 2 - deliberate reflection. Teachers identify critical classroom events and give explanations for them.
- Level 3 - critical reflection. Teachers go beyond identifying and explaining critical events to suggesting alternative actions.
Teacher educators therefore should assist PST to move from one level to another as they engage them in activities that promote development of reflective practice. The use of videos in preservice teacher can provide teacher educators opportunity to help PST develop reflective practice (Sherin & van Es, 2009). My study explores the role of video-based lesson analysis in developing the PST reflective practice and mathematical knowledge for teaching (MKfT). It parallels the Viewing, VIDEO-LM project being run in Israel by Karsenty, Arcarvi and Nurick (2015). The project aims at enhancing the reflective skills of in-service secondary mathematics teachers and to promote the development and enrichment of their MKfT using video-based lessons and a framework they designed for this purpose, the Six Lens Framwork (SLF). Santagata and Yeh (2014) claim a gap in research that has explored the role of analysing the video-based lessons in pre-service teaching.

THEORETICAL FRAMEWORK

Our research employs the SLF both as the conceptual and theoretical framework. Its six lenses that are used for guiding reflections are:

- mathematical and meta-mathematical ideas which relates to the mathematical concepts and ideas developed in the screened lesson;
- explicit and implicit goals, that is, the goals the screened teacher is working to achieve through the lesson;
- tasks and activities refer to the work the teacher gives students that will help him achieve the lesson goals;
- interactions with students is how the teacher interacts with the students during the lesson;
- dilemmas and decision-making are the challenges with regard to mathematics and its teaching; and
- beliefs relate to the teacher’s orientation with regard to mathematics and its teaching.

RESEARCH CONTEXT AND METHODOLOGY

Our qualitative case study is being conducted at a selected university in South Africa with third year Bachelor of Education Foundation Phase (FP) PST. In a class of 54 PST, 14 volunteered to participate in the research. The data is collected through lecture observations, written and recorded reflections, assignments and interviews. This paper reports on preliminary data on the written individual PST reflections from one of the lectures observed. The focus of the paper is on one of the six lenses, the tasks and activities.

DATA PRESENTATION AND ANALYSIS

Data is being analysed using content analysis where the PST reflections on each lens are analysed to depict what level of reflective practice is evident. The utterances are coded using Muir and Beswick
Muir and Beswick (2007) identifies three levels of reflection that teachers go through as they learn to be reflective practitioners: the technical description, deliberate reflections, and critical reflections. Each of these levels is described in Table 1 below.

The utterances that described what was happening in the classroom, such as the teacher/learners' actions and the mathematical problems, without giving explanations on why things were done that way or why the problem was what it was, and how it affected the teaching and learning of mathematics, were taken as technical descriptions. When the description was followed by some reasoning, they were regarded as deliberate reflections; and when the PST went further and suggested what could have been done differently, then it becomes a critical reflection.

The reflections are based on a video of a grade R teacher teaching mathematics through a story where five children were under one big umbrella when the other umbrella (small) had no one. One child complained about this and they started moving one by one from the big umbrella to the small umbrella until all were under the small umbrella. The learners acted out this story in class during that lesson and discussed the effects of the move. The tasks and activities involved learners recognising the muchness of numbers, when they had to tell how many children are under each umbrella after one child moves from the big umbrella to the small one. They identified the number symbols that match with numbers names, compared the number of children under each umbrella, hence developing the mathematical language, recognising patterns and relationships between numbers. In figures 1, 2 and 3 we share some of the PST reflections.

Table 1: Two-dimensional framework for analysing teachers’ reflections

<table>
<thead>
<tr>
<th>Reflection Lenses</th>
<th>Levels of reflection</th>
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<tbody>
<tr>
<td><strong>Technical description</strong></td>
<td><strong>deliberate reflection</strong></td>
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<tr>
<td>Mathematical and meta-mathematical</td>
<td>Teachers describe the classroom experiences</td>
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<td>ideas</td>
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<td>teaching without considering the importance</td>
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<td>of those experiences</td>
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<td>Goals</td>
<td>Teachers identify critical classroom events and give explanations for them</td>
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<tr>
<td>Tasks and activities</td>
<td>Teachers go beyond identifying and explaining critical events to suggesting alternative actions</td>
</tr>
<tr>
<td>Interactions</td>
<td></td>
</tr>
<tr>
<td>Beliefs</td>
<td></td>
</tr>
<tr>
<td>Dilemmas and decision-making</td>
<td></td>
</tr>
</tbody>
</table>
DISCUSSION

In our analysis of the preliminary data focusing on the task and activities showed that the PST were generally describing the classroom occurrences and very few PST attempted to give explanations for those occurrences. The descriptions were also at varying levels where some PST could describe the classroom occurrences clearer than others confirming what Geiger et al. (2015) proposed that teachers do not develop reflective practice at the same pace. Mandy’s reflections (figure 1) are not clear what lens she was reflecting on and what exactly was happening in the classroom. Lutho’s
description of what was happening in the classroom is clearer however, he did not attempt to explain why. On the other hand, Sharon’s reflections describe and attempts to explain. For example, Sharon explains that the activity was read to develop the learners’ vocabulary and (sums) probably implying learners should calculate.

CONCLUSION

While SLF can very useful for guiding teachers to reflect, it was not very effective in PST reflecting at varying levels of the technical descriptions. This suggests a need to develop a framework that can be used to measure the different levels of reflection within each level of reflection prescribed by Muir and Beswick (2007).

REFERENCES

EXPLORING A MODEL FOR TEACHING GEOMETRY: POLYGON PIECES AND DICTIONARY TOOLS FOR THE MODEL

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Abstract
Many mathematics teachers find it difficult to stimulate learners’ interest in learning geometry. Learning becomes boring when what is being learnt is not well conceptualised. This paper investigated a model that integrates mathematics dictionary and polygon pieces in teaching and learning of geometry to grade 8 learners. The purpose of this paper is to explore how polygon pieces and dictionary mediate successful learning of geometry from learners’ views. The research study’s sample comprised nine Grade 8 learners in one of the high schools in Eastern Cape Province of South Africa. The sample was purposely selected from the cohort of 56 students, based on the results of the diagnostic test. By employing a qualitative approach through exploration data were gathered from semi-structured interviews and key-words-in-context analysis was implemented and reported in themes. The study found that polygon pieces assisted by mathematics dictionary enhance learners learning of geometry. We recommend mathematics teachers to integrate polygon pieces assisted by mathematics dictionary in the teaching and learning of mathematics.

Keywords: unpack meaning, polygon pieces, conceptual understanding, properties of triangles, geometry

Introduction
Most learners’ challenges in conceptual understanding of geometry in most of the schools have created the need to develop innovative methods of teaching and learning geometry. Geometry being the compulsory subject in most of the science career fields, for example in architectural design; engineering and different areas of construction sector, it is noted that geometrical skills acquired at primary and high school levels are also of worthwhile (Alex & Mammen, 2014; Van den Heuvel – Panhuizen, Elia & Robitzsch, 2015). Research shows that problems encountered by learners in learning geometry are a result of how the subject is taught at all levels from primary to high school (Fujita & Keith, 2003). The study done by Van Hiele (1999) reveals that school geometry is presented based on certain principles assuming that learners think at a formal logical level, yet most of the learners lack the basic conceptual understanding about geometry (Steele, 2013). This calls for mathematics teacher to be knowledgeable creative enough in the subject matter.
The existence of real-life fields of study that require geometry have made the authorities of education systems to consider geometry with the highest priority in school curricula right from primary level (Clements & Sarama, 2011). Hence, Current research outputs show constant consideration in mathematics education in general and geometry education specifically (Alex & Mammen, 2014; Moss, Hawes, Naqvi & Caswell, 2015).

It is evident that traditional teaching practices deny learners creativity and cripple learners' problem-solving skills. Mathematics teachers should understand that geometric conceptual understanding does not come suddenly; it requires an instructional process that matches figural and conceptual components using specific intervention strategies and well-integrated teaching and learning resources, in this case the integration of polygon pieces and mathematics dictionary (Luria, 1976; Bussi & Frank, 2015). Most studies focus on the achievement results when physical manipulatives were used in the teaching and learning of mathematics. However, they do not focus on the integration of polygon pieces assisted by mathematics dictionary in the teaching and learning of geometry. Therefore, the paper adds a new dimension to the research on the use of polygon pieces assisted by mathematics dictionary for instruction.

According to Van Hiele (1999), vocabulary plays an important role in developing geometrical understanding hence we recommend the integration of polygon pieces and dictionary in the teaching and learning of geometry.

In response to the call made by Trends in Mathematics Science Study (2015) that says most schools need interventions to improve students’ performance in mathematics (Reddy, Visser, Winnaar, Arends, Juan, Prinsloo & Isdale (2016)). This paper aims to respond to the call by exploring geometry teaching and learning model that integrates polygon pieces assisted by mathematics dictionary to help in enhancing learners’ conceptual understanding of geometry.

The paper sought to answer the following question: How will the use of polygons pieces as physical manipulatives assisted by mathematics dictionary in teaching and learning of geometry influence learners’ conceptual understanding of geometry concepts, specifically properties of polygons?

THEORETICAL FRAMEWORK

The van Hiele model of geometric thinking for learners’ learning of geometry was used to frame the study to account for the exploration of the model that make use of polygon pieces assisted with mathematics dictionary. The model is described as follows:

*Level 0 of geometry thinking – visualization:* At this level, polygons are judged according their visual characteristics where by learners may for example judge a square as not being a parallelogram.
Level 1 of geometry thinking – analysis: At this level, through reflection and testing geometric shapes’ characteristics gradually emerge and then used to describe the given shape.

Level 2 of geometry thinking – abstraction: At this level, figures are well ordered. They are construed one from another. Properties are arranged chronologically when describing a certain shape.

Level 3 of geometry thinking—formal deduction: At this level a learner’s rational reasoning is considered to be at an advanced level of making meaning out of the given figures. For instance, the learner can prove situations with valid reasons.

Level 4 of geometry thinking – rigor: At this level, learners can make a comparison between systems based on diverse axioms and can study geometric concepts without tangible means (p. 311).

Clements and Battista (1991) extended the levels of van Hiele by adding the pre-cognition level (level 0) to give us five levels of geometry thinking.

Van Hiele (1999) suggests that in order to ensure smooth transition from one level of geometric thinking to the next, teaching and learning must be in a sequence portrayed in the five-phase structure, namely:

Phase 1: Inquiry phase: In this phase, resources lead learners to discover and realise definite features of geometric figures.

Phase 2: Direct orientation: In this phase, activities are presented in such a way that their features appear steadily to the learners, i.e. through brainteasers that disclose symmetrical sections.

Phase 3: Explication: The terms are introduced and learners are encouraged to use them in their discussion and written geometry exercises.

Phase 4: Free orientation: The teacher presents a variety of activities to be done using different approaches and this instils in learners’ capabilities to become more skilled in what they already know.

Phase 5: Integration: Learners are given opportunities to summarise what they have acquired during instruction, possibly by creating their personal activities.

RESEARCH DESIGN

This paper employs qualitative inquiry to get insight to the conceptual development of geometry ideas through semi-structured interviews that were later analysed and will be reported using a thematic report. A case study approach is adopted in this paper. A diagnostic was administered to the students with the aim of identifying students’ challenges that will be addressed by the intervention.

Based on the need arose in the diagnostic test, in phase two, the intervention programme was designed and administered to address not only the alternative conceptions learners demonstrated in the diagnostic test but also to teach the concepts of the properties of triangles in an informal activity-based way so that learners would be able to identify, classify and name triangles based on
their properties. In the intervention programme, polygon pieces assisted by mathematics dictionary were used in to engage learners in developing conceptual understanding of the properties of triangles.

**Intervention**

In every intervention activity, each learner was provided with an A4 paper. For instance, on the paper, triangle ABC was drawn – along with the A4 paper were the two copies of triangles ABC provided.

![Figure 1: How the intervention process of cutting out polygon pieces](image)

Figure 1 shows how the process of cutting out line segments and angles from the given triangle was done. The comparison was done by placing each of the cut out line segments or angles one at a time on top of the other line segment or angle in the original triangle and for every measure taken the results were recorded down. The findings of how the line segments and angles were related in the given triangle were used to describe the properties of that particular triangle. In this activity no rulers and protractors were used, only cut out line segments and angles were used. Even in describing how line segments were related, the informal mathematical language was used, i.e. longer than, shorter than or equal to. For angles, learners would use greater than, smaller than and equal to. When the properties were identified and described the name of that particular triangle was to be written down, the mathematics dictionary was made available to help in enhancing mathematics vocabulary and terminology. The dictionary was used whenever learners felt a need to define and comprehend geometric concepts which were of higher order level.

In each of the planned intervention activities, learners were supposed to answer each and every question after measuring and comparing angles and sides of the given triangles using polygon pieces. Each intervention activity was scheduled for one hour. The total time spent to complete the nine intervention activities was nine hours. The use of polygon pieces assisted by mathematics dictionary
was applied in all the intervention activities. As shown in Figure 1 activities were done by cutting out the line segments and angles from the copies provided in order to explore the properties of specific provided triangles. The cut pieces were for the conceptual development of learners in geometry (Hwang & Hu, 2006).

Intervention activity 1 consisted of eight questions. All eight questions were aligned to different levels of geometric thinking as follows: question 1.1 was aligned to level 0-visualisation, questions 1.2; 1.4 and 1.5 were aligned to level 3-formal deduction, questions 1.3 and 1.6 were aligned to level 2-abstraction, and question 1.7(i) – (ii) were aligned to level 1-analysis.

Intervention activity 2 had only two main questions that required learners to classify triangles based on their properties and to match the given properties of triangles with the relevant triangles. Both questions were at level 1-analysis of van Hiele theory of geometric thinking.

Intervention activity 3 required learners to identify triangles by name and apply the use of symbols. This intervention had three main questions of which question 3.1 was related to levels 0- visualisation and 1-analysis of the van Hiele theory geometry thinking, while questions 3.2 and 3.3 were aligned to level 1-analysis of van Hiele theory.

Intervention activity 4 had one question with sub-sections 4.1 to 4.6 which required learners to match given triangles with the list of properties given. The activity was at level 1-analysis of the van Hiele theory of geometric thinking.

Intervention activity 5 consisted of two questions 5.1(i) – (iii) and 5.2(i) – (v) which required learners to identify and explore the properties of a right-angled triangle. All questions in this activity were aligned to level 1-analysis, except question 5.2 (vi) which was aligned to level 2- abstraction of geometric thinking.

Intervention activity 6 requires learners to explore the properties of obtuse-angled triangles. There are only two questions which are divided into sections as shown in appendix 17. The contents of both questions 6.1(iii) and 6.2(i) – (iii) were at level 1-analysis of the van Hiele levels of geometric thinking while 6.2(iv) – (vi) were at level 2-abstraction of the van Hiele levels of geometric thinking. According to the structure of the intervention activity 6(i) and 6.1(ii) were instructions which learner were supposed to follow in order to do question 6.1(iii).

Intervention activity 7 consisted of questions 7.1 and 7.2 in which learners were asked to explore the relationship of angles and line segments by using the physical manipulatives. In this intervention activity questions 7.1(iii) and 7.2 (i) – (iii) were aligned to level 1-analysis of the van Hiele levels of geometric thinking while question 7.2(iv) – (vi) was at level 2-abstraction of the van Hiele levels of geometric thinking.
Intervention activity 8 contained questions 8.1 to 8.4 which required learners to explore and discover the properties of an equilateral triangle. Questions 8.1(i) – (iii) were aligned to level 0- visualisation of the van Hiele levels of geometric thinking while question 8.1(iv) and 8.2(i) - (iii) were aligned at level 1 of the van Hiele levels of geometric thinking. Question 8.3(i) – (ii) was at level 3-formal deduction of the van Hiele theory while question 8.4 was at level 2-abstraction of the van Hiele theory.

Intervention activity 9 consisted of questions 9.1 to 9.4 which focused on investigating properties of an isosceles triangle using polygon pieces. In this activity, questions 9.1(i) – (iii) were at level 0- visualisation of the van Hiele theory. Questions 9.1(iv), 9.2(i) – (iii) were at level 1 of the van Hiele levels of geometric thinking. Question 9.3(i) – (ii) were at level 3-deduction while question 9.4 was at level 2-abstraction of the van Hiele levels of geometric thinking.

The collected data from semi-structured interviews were analysed thematically applying keywords-in-context analysis technique. This analysis exposes how the words have been used in context (Fielding & Lee, 1998) by matching words “that appear before and after keywords” (Leech & Onwuegbuzie, 2007:566).

FINDINGS

Arose from the data analysis of the transcribed semi-structured interviews the following themes emerged:

**Assisted conceptualisation**

**Cutting**

Five of the eight learners reflect on cutting as a tool that supported their learning of some geometric concepts. L3 assert that cutting out polygon pieces and creating triangles made him/her learn properties of triangles. L4 states that using cut out pieces made her/him able to identify the types of triangles. L6 suggested that the use of cut angles and line segments should precede the measuring angles of shapes using the protractor in order to stimulate inquisitive thought and give meaningful explanations. L7 mentions that the cut-out pieces made her/him able to discover equal angles in triangles. L9 liked the use of cut polygon pieces for the reason that independent learning was enhanced without being told how an isosceles triangle looked like.

**Constructing**

Three of the eight learners mentioned that construction task they were engaged in helped them learn geometric shapes and their properties. L1 stated that construction and measuring skills improves his/her understating of geometric terms. L3 suggested that the use of polygon pieces could also be used to explore the association between two bisected angles. L8 concluded that polygon pieces can also be used for the construction of a number of geometric shapes.
Measuring
Cut out pieces allowed learners to measure sides and angles. L2 said that measuring skills improves the understating of geometric terms. L4 further said that the use of polygon pieces to determine the relationship between angles and sides in a given triangle during the intervention programme enhanced his/her measuring skills. L5 asserts that important mathematical skills and knowledge were acquired for the reason that the programme focused on how to measure and not on what it means to measure. L6 suggested that the use of cut angles and line segments should precede the measuring angles of shapes using the protractor in order to stimulate inquisitive thought and give meaningful explanations.

Polygon pieces exploration encourages inquiry
Learners preferred use of polygon pieces as nurturing their geometric knowledge. L1 preferred to be taught geometry and other mathematics topics using polygon pieces in order to enhance conceptual understanding. L2 proposed that the best way to help learners comprehend the relationship of angles and sides in a triangle was to engage learners in the activities that made use of polygon pieces since they allowed learners to measure angles and lengths of sides of triangles. L3 recommended that the teaching and learning of mathematics, for example, geometry using polygon pieces was interesting and was of meaning. L4 indicates that the use of polygon pieces that were integrated into the teaching and learning of geometry helped this learner with conceptual understanding of the properties of different triangles.

Enhanced vocabulary
Transferring informal vocabulary aided by dictionary
L1 was optimistic that the integration of polygon pieces and mathematics dictionary in the learning of geometry instills essential skills in a learner’s mind; for example, construction and measuring skills and improves the understating of geometric terms. The polygon pieces assisted by mathematics dictionary allowed learners to go into an investigation process of the properties of different triangles (L3 & L9). According to L2, L4, L5, L6 and L9, the use of polygon pieces assisted by the dictionary made it easy for them to classify and define triangles, for example, L2 said that “...and also as I am speaking, I now know well the names of triangles and how to write their names correctly.”

DISCUSSION OF FINDINGS
The findings indicate clearly that learners learnt, understood, measured, constructed and gained knowledge about triangles. In addition, vocabulary addition can be observed from isosceles, obtuse, scalene, and angles. It can also be observable that the congruency concept is also learnt but not yet at the level of abstractness. The evidence from learners’ responses during the semi-structured interviews suggests that the integration of polygon pieces and mathematics dictionary into the teaching and learning has a positive influence.
The study has revealed that learners not only struggle with proving of geometric theorems, but also geometric terminology becomes a barrier in the learning of geometry. The aid of mathematics dictionary in the lesson strengthens the conceptual understanding of a variety of geometric terms. Teachers must understand that one of the constructivism principles emphasises that teaching is not just dissemination information to the learners, but is involves creatively integrating teaching and learning resources into the lesson to enhance learning processes.

We recommend the integration of mathematics dictionary into teaching and learning geometry to enhance learners’ English and mathematics language proficiency.

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ABSTRACT
The National Council of Teachers of Mathematics (NCTM), (2000) and the South African Department of Education’s Curriculum and Assessment Policy Statement (CAPS), (2011) consider problem-solving as an essential aspect of mathematics teaching and learning. Despite the American and South African curriculums emphasizing the teaching of mathematical problem-solving, nothing much is known about how prospective teachers’ beliefs about mathematical problem-solving from these two countries compare and contrast. The key intention of the study was to explore, compare and contrast American and South African pre-service teachers’ beliefs about mathematical problem-solving. A total of 103 Bachelor of Education first year students from a University in Gauteng, South Africa and 67 students from a University in America were selected to participate in the study. Data were derived from a questionnaire that focused on pre-service teachers’ beliefs on the nature of mathematical problem-solving and the preliminary findings were that the participant teachers from the two countries perceived the meanings of mathematical problem, good mathematical problems and mathematical problem-solving differently.

INTRODUCTION
Problem-solving is at the heart of mathematics (Halmos, 1980) and has been regarded as an important characteristic of the teaching and learning of mathematics for a long time (Liljedahl, Bruder, Santos Trigo, & Jurado, 2016). Mayer and Wittrock (2006, p. 287) define the process of problem-solving as a ‘form of cognitive processing you engage in when faced with a problem and do not have an obvious method of solution’. Polya (1957) see it as finding a solution to a problem that is unknown and identifies steps in the problem-solving process as understanding the problem, devising a plan, executing the plan and looking back at the solution strategy. These steps are enhanced by a problem-solver’s belief about whether the given problem is worth solving. Mathematical beliefs are value judgments towards mathematics that a problem-solver has obtained from previous experiences (Raymond, 1997) and are the ‘perspectives with which one approaches mathematics and mathematical tasks’ (Schoenfeld, 1985, p.45). Beliefs are important because they form attitudes and emotions that regulate the decisions made during problem-solving.

This study examined pre-service teachers’ beliefs about mathematical problem-solving at their entry into university. Pre-service teachers usually bring with them to university beliefs towards
mathematical problem-solving that they attain during their years at primary and high school. It is important that these beliefs are known as they can hinder prospective teachers from developing new mathematical problem-solving aptitudes and proficiencies. As future teachers, pre-service teachers need to develop positive mathematical problem-solving beliefs because what teachers believe influences what they teach, how they teach and what is learned in the classroom (Ernest, 1989). Inappropriate beliefs of teachers about mathematical problem-solving are widely seen as an obstacle to making the former central to the teaching and learning of mathematics (Schoenfeld, 1994).

Research on teachers’ problem-solving-related beliefs is limited (Xenofontos & Andrews, 2014) and this was the first study to be done to compare American and South African pre-service teachers’ beliefs on mathematical problem-solving. We hope this study filled gaps in the literature on how pre-teachers perceive mathematical problem-solving across the two different countries.

PROBLEM FORMULATION

A number of researches have investigated American pre- and in-service teachers’ beliefs about mathematical problem-solving. While recent research (Chirinda & Barmby, 2018) has investigated in-service South African teachers’ views on the teaching of mathematical problem-solving nothing much is known about South African prospective teachers’ beliefs about the former and how they compare to teachers from other countries that also emphasize the teaching of mathematical problem-solving. We formulated the following research problem:

How does American and South African pre-service teachers’ beliefs about mathematical problem-solving compare?

More specifically, to find answers for the main research problem, the following research sub-questions govern the research methodology:

1. What are American pre-service teachers’ beliefs about mathematical problem-solving?
2. What are South African pre-service teachers’ beliefs about mathematical problem-solving?
3. Is there a significant difference between the mathematical problem-solving beliefs of American and South African pre-service teachers?

REVIEW OF LITERATURE

Many researchers (Carpenter, Fennema, Peterson, Chiang, & Leof, 1989; Liljedahl et al., 2016; Polya, 1957; Schoenfeld, 1985; Venkatakrishnan & Graven, 2006) agree that problem-solving is an important goal of mathematics teaching and have accentuated its role in improving learners’ achievement in mathematics. Carpenter et al. (1989) report that when emphasis is positioned on problem-solving in the learning of mathematics then:

i) learners’ attention on ideas and sense making increases;
ii) there is liberty by learners to construct own strategies,
iii) mathematical problem-solving skills are enhanced, and
iv) learners' cognition increases.

Beliefs are important in mathematical problem-solving because when a problem is posed learners must view it as worth solving and must give it attention and genuine effort (Schoenfeld, 1992). A number of studies have been conducted to examine mathematics teachers’ beliefs on mathematical problem-solving. Kloosterman and Stage (1992) examined problem-solving beliefs of learners and concluded that a person’s mathematical beliefs affect their learning and problem-solving. Xenofontos and Andrews (2014) compared pre-service teachers’ beliefs in Cyprus and England, about the nature of mathematical problems and problem-solving. Their findings were that pre-service teachers’ beliefs are culturally located.

THE RESEARCH METHODOLOGY

Upon receiving ethical clearance, a questionnaire was administered to a total of 103 Bachelor of Education first year students from a university in Gauteng, South Africa and 67 students from a University in America. The questionnaire was validated for face, construct and content validity and was also pilot-tested. The questionnaire solicited among other aspects participants’ understanding of mathematical problem, good mathematical problem and mathematical problem-solving. Participants were also required to give an example of a good mathematical problem and to describe themselves as problem-solvers. Qualitative data from the questionnaire was analysed through inductive data analysis techniques. Quantitative data was analysed using the statistical package SPSS.

FINDINGS AND CONCLUSION

The study is still on-going and at the time of writing this paper we had begun data analysis. The preliminary findings were that participant teachers from the two countries perceived the meanings of mathematical problem, good mathematical problem and mathematical problem-solving differently.

South African pre-service teachers: 68% of participants viewed a mathematical problem as a statement with an unknown variable. 4% left the statement blank and 28% wrote absurd statements like: ‘a mathematical problem is a question that needs deep analysis’; ‘anything that needs to be solved and at the end must have a solution’; ‘a problem without a solution which requires mathematics skill to draw the solution’; ‘an expression or equation that is not solved’, etc. 55% viewed a good mathematical problems as real life problems that challenge learners’ thinking, 43% believed that a good mathematical problem is one that allows learners to draw on their prior knowledge and 12% wrote different statements. All participants viewed mathematical problem-solving as an application of computational skills.
**American pre-service teachers**: Most participants defined a mathematical problem as one that does not have a readily known algorithm that guarantees the solution and a good mathematical problem as one that requires higher-order thinking. A large percentage of participants viewed mathematical problem-solving as when learners use previously acquired skills to tackle a given problem.

The study reported in the paper sought to compare and contrast American and South African pre-service teachers’ beliefs on mathematical problem-solving and only preliminary findings were given.

**REFERENCES**


AN INVESTIGATION OF EARLY NUMBER LEARNING AMONG PRIMARY II PUPILS USING MATHEMATICS RECOVERY MODEL IN NIGERIA

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unazeef@gmail.com

ABSTRACT
This paper explores the use of Mathematics Recovery (MR) model as an intervention tool for assessing early number learning among primary II pupils in Bauchi State of Nigeria. The research is an intervention study that is based on the pupils’ levels and stages on the Learning Framework in Number (LFIN). A qualitative Case Study research design was used to investigate the case of four (4) pupil’s early number learning. An LFIN assessment individual orally administered interviews was used for individual pupil. A qualitative data analysis was used to describe and explain the strategies they used when dealing with early numbers. The findings of the study reveal the usefulness of MR model in Nigerian context and also provide a possible solution to the pupils’ poor performance towards mathematics.

INTRODUCTION

There is a growing concern by stakeholders in education that the performance of primary school pupils in mathematics in Nigeria is not encouraging (Aremu & Salami, 2013) and the National Common Entrance Examination (NCEE) reports, (2010-2015). Despite the efforts by the Federal Government in collaboration with Millennium Development Goals (MDG’s) and other non-governmental organizations, through retraining of the primary school teachers, the problem still persist (NCEE, 2010-2015; Obidoa, Micheal & Onwubolu, 2013). Perhaps, the approach of in-service teacher professional development was based on the view that, developing teacher capacity serve as a mechanism for improving teaching and in turn improve pupils’ performance (Aremu & Salami, 2013). This is not always the case as some pupils might have knowledge gaps that may be difficult for them to cope within whole class teaching. Some of the causes of knowledge gap are; individual characteristics, inadequate/inappropriate teaching, absence from school resulting to gaps in mathematical learning, and lack of pre-school or home experience with mathematical activities (Dowker, 2003; 2004; Wright, Martland & Stafford., 2006).

Research has shown that children with knowledge gaps are in need of special intervention to remediate what might hinder their progression in later school years (Mallum & Haggai, 2000; Yusuf, Ohando & Yusuf, 2002). As a result of pupils difficulties, Wright and his colleagues in Australia, developed a program for teaching and intervention at an early stage called the Mathematics Recovery (MR). The model was design to address pupil’s mathematics knowledge gaps among
children in their early years of schooling (6 to 8 years). In addition, the model provide a comprehensive framework that provide assessment which assess the students’ knowledge gap, as well as providing teaching intervention to address that gap. Although the MR program has been used in many countries and culture, in an attempt to find solution for bridging this knowledge gaps among pupils in Nigerian primary schools, the present study aims at using the MR model as assessment mechanism to understand the development of primary II pupils’ basic number concepts.

THEORETICAL FRAMEWORK, METHODOLOGY AND ANALYTICAL TOOLS

This study was based on the broad socio-cultural perspective where learning is seen as an active construction of knowledge through social interactions with others. Learners are encouraged to construct solutions that they find acceptable, given their current ways of knowing (Yackel, Cobb & Wood, 1991). The challenge is then to find activities that are likely to be problematic for the learners. This forms the basic orientation of MR: it involves exploring children’s construction of arithmetical strategies with a focus on finding favourable instructional activities that support the construction of arithmetical knowledge (Wright, et al, 2006).

The Learning Framework in Number (LFIN) that was developed in Australia by Wright and his colleagues (2006), provides a useful way of assessing the pupil’s mathematical progress. LFIN has two broad purposes, firstly, it can provide a rich, detailed description of the pupil’s current knowledge of early number and secondly, it leads to determination of levels of knowledge across the stages of the framework which provide rich data that can be used in the preparation of the intervention mechanisms that can bridge the knowledge gap for individual child (Wright, et al, 2000). This assessment involves the use of Learning Framework in Number. The LFIN is organized into four parts which consist of eleven (11) aspects of early number learning. The four parts are label as A, B, C and D.

- The part A consist of early arithmetical strategies, and base ten arithmetical strategies.
- The part B consist of Forward Number Word Sequences (FNWS), Backward Number Word Sequences (BNWS) and Numeral Identification (NUM. I.D.).
- Part C consist of combining and partitioning, spatial patterns and subitizing, temporal sequence, finger patterns, and quinary-base (base five) strategy,
- While lastly part D consists of early multiplication, division and fractional knowledge. As an intervention model, the program involves one-one interview and teaching session with pupils in their early school years.

For the purpose of this research, the focused was on part A and B of the LFIN because it deals with the relative sophistication of child strategies for counting, adding and subtraction. Each of the key aspect of the LFIN are further elaborated into a progression of levels and stages with each model describing the characteristics of the levels or stages (wright et al. 2006). Detailed descriptions of the levels and stages as used in this research was presented in table 1, 2, 3 and 4 respectively.
**Table 1: Stages of Early Arithmetical Learning SEAL**

<table>
<thead>
<tr>
<th>STAGES</th>
<th>TASKS</th>
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</thead>
<tbody>
<tr>
<td>Stage 0: Emergent counting</td>
<td>Child cannot count visible items</td>
</tr>
<tr>
<td>Stage 1: perceptual counting</td>
<td>Can count perceived items but <strong>not in a screened</strong> collection</td>
</tr>
<tr>
<td>Stage 2: Figurative Counting</td>
<td>Can count screened collection but <strong>counting start by one</strong> instead of</td>
</tr>
<tr>
<td></td>
<td>counting-on</td>
</tr>
<tr>
<td>Stage 3: initial number</td>
<td>Uses <strong>counting-on</strong> rather than counting from one to solve addition</td>
</tr>
<tr>
<td>sequence</td>
<td>and missing addend and counting down from to solve remove item</td>
</tr>
<tr>
<td></td>
<td>but not counting down-to to solve missing subtrahend.</td>
</tr>
<tr>
<td>Stage 4: intermediate number</td>
<td>Uses <strong>count-down</strong> to strategy to solve missing subtrahend. The child</td>
</tr>
<tr>
<td>sequence</td>
<td>can also choses count-down to or count-down from strategy.</td>
</tr>
<tr>
<td>Stage 5: Facile Number</td>
<td>Child uses <strong>non-counting by ones</strong> strategies and involve procedures</td>
</tr>
<tr>
<td>sequence</td>
<td>other than counting by ones.</td>
</tr>
</tbody>
</table>

**Table 2: Base Ten Arithmetic**

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>TASKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1: initial concept of</td>
<td>Child does not see ten as a unit of any kind</td>
</tr>
<tr>
<td>ten</td>
<td></td>
</tr>
<tr>
<td>Level 2: intermediate</td>
<td>Child can see ten as a unit compose of ten ones</td>
</tr>
<tr>
<td>concept of ten</td>
<td></td>
</tr>
<tr>
<td>Level 3: Facile concept of</td>
<td>Child can solve addition and subtraction task involving tens and ones</td>
</tr>
<tr>
<td>ten</td>
<td>without using material or representations of materials</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 3: Forward Number Word Sequences FNWS**

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>TASKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0: Emergent FNWS</td>
<td>Child cannot produce number from 1 to 10</td>
</tr>
<tr>
<td>Level 1: Initial FNWS</td>
<td>Can produce numbers from 1 to 10 but cannot produce a number just</td>
</tr>
<tr>
<td></td>
<td>after a given number</td>
</tr>
<tr>
<td>Level 2: Intermediate FNWS</td>
<td>Can produce FNWS from 1 to 10 and a number after a given number but</td>
</tr>
<tr>
<td></td>
<td>drops back to 1 when doing so</td>
</tr>
<tr>
<td>Level 3: Facile with FNWS</td>
<td>Can produce FNWS from 1 to 10 and a number word after a given number</td>
</tr>
<tr>
<td></td>
<td>without dropping back to 1 but cannot produce a number beyond</td>
</tr>
<tr>
<td>Level 4: Facile with FNWS up</td>
<td>Can produce FNWS from 1 to 30 and a number word after a given number</td>
</tr>
<tr>
<td>to 30</td>
<td>without dropping back to 1 and can produce numbers beyond</td>
</tr>
<tr>
<td>Level 5: Facile with FNWS up</td>
<td>Can produce FNWS from 1 to 100 and a number word after a given number</td>
</tr>
<tr>
<td>to 100</td>
<td>without dropping back to 1 and number beyond</td>
</tr>
</tbody>
</table>

**Table 4: Backward Number Word Sequences BNWS**

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>TASKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0: Emergent BNWS</td>
<td>Child cannot produce BNWS from 10 to 1</td>
</tr>
<tr>
<td>Level 1: Initial BNWS up to 10</td>
<td>Child can produce BNWS from 10 to 1 but cannot the number word just</td>
</tr>
<tr>
<td></td>
<td>before a given number</td>
</tr>
</tbody>
</table>
Level 2: Intermediate BNWS up to 10  
Child can produce BNWS from 10 to 1 and a number word just before a given number but drops back to 1 when doing so

Level 3: Facile with BNWS up to 10  
Child can produce BNWS from 10 to 1 and a number just before a given number without dropping back to 1 but has difficulty for numbers beyond 10

Level 4: Facile with BNWS up to 30  
Can produce BNWS from 30 to 1 and a number just before a given number without dropping back to 1 and may be able to produce number beyond

Level 5: Facile with BNWS up to 100  
Can produce BNWS from 100 to 1 and a number just before a given number without dropping back to 1 and may be able to produce number beyond

Also, because of the importance of SEAL, this study has focused more on it assessment. All the assessments are one-to-one interview base to determine the levels or extent of the pupil’s knowledge and the strategies they used in solving the aspect of early numeracy. This is done by profiling each child based on the interview. From the profile, one can identify what are the things that these children are struggling with so as to guide on the specific intervention each child requires. This is important as research has shown that children who are weak in their early classes tend to remain in such position throughout their schooling and often give up in mathematics (Aubrey, 1993; Wright, 1991; 1994; Young-Loveridge, 1989; 1991).

One of the main features of MR program is its application in many educational context and different countries (Wright, et al, 2006). The program has been implemented in many different countries such as; Canada, United Kingdom, United State of America, Bahamas, Britain, New Zealand, Ireland, Scotland, South Africa, among others. The idea in all these is to bridge the numeracy skills and knowledge gaps among primary school pupils.

However, no literature shows its application in the Nigerian context. Therefore, this study aims to break grounds in revealing the possibility of applying this model in the Nigerian context. This is needed more in Nigeria due to evidence of frequent poor pupils’ mathematics performance at the end of primary school as contained in the National Common Entrance Examination (NCEE), (2010 – 2015) reports. Some studies have indicated that pupils’ negative attitude towards mathematics which is creating a situation where students run away from any mathematics related courses in their further studies is as a result of the consequences of numeracy knowledge gaps (Askew, 2013; Aremu & Salami, 2013).

FINDINGS

The findings of all the four case participants for the LFIN interviews was presented in Table 5 where pseudo names were used to replace the identity of the participants.
In terms of the SEAL Model, it shows that 2 out of the four participants were at stage 3: Initial number sequence because they use counting-on rather than counting from one while solving problems related to addition and missing addend in the LFIN interview. This stage was characterized by pupils’ ability to use counting-on strategy in solving addition and missing addend task and can also use a count-down-from strategy to solve remove items. Example; when presented with the task of 9 + 6 both screened, they normally use fingers and coordinate the counting by saying ten, eleven, twelve, thirteen, fourteen and fifteen which indicate unit counting. Another incidence of counting-on was observed when presented with the task of 16 – 12 and 17 – 14. Also, only one of the participants was at stage 5: Facile number sequences which is a stage that was characterized by pupil’s ability to use a non-counting by one strategy when presented with the interview tasks.

On the Forward Number Word Sequences, 75% of the pupils are at level 5: Facile with forward number word sequences up to 100 where they can produce FNWS up to 100 and a number word after a given number in the range without dropping back and they produced number beyond in the LFIN interview.

For the Backward Number Word Sequences (BNWS), 50% of the pupils are at level 4: Facile with BNWS up to 30 and the remaining 50% were at level 5: Facile with Backward Number word sequences up to 100 where they can produce BNWS from 100 to 1 and a number just before a given number without dropping back to one.

For the Numeral identification, there are five levels ranging from 0 to 4. 25% of the pupils were at level 2: Numerals to 20 while 75% were at level 3: numerals to 100 in the Pre-LFIN interview.

In terms of base-ten arithmetical strategies, out of the three levels, 75% representing 3 of the pupils were at level 2: intermediates concepts of ten in LFIN interview which is a level that was characterized by pupil’s ability to sees ten as a unit composed of ten ones.

Therefore, this study shows that Mathematics Recovery sessions was useful for assessing the pupil’s levels of development in terms of their arithmetical strategies and has potentials for developing pupils early number understanding. This indicates the development in terms of the early number understanding among primary II pupils.

CONCLUSION
The Mathematics Recovery Assessment and Intervention model that was developed in Australia was found to be useful in identifying the areas of early number learning difficulties among Nigerian pupils.

REFERENCES


**A SOCIAL REALIST ANALYSIS OF THE MATHEMATICS METHODOLOGY CURRICULA FOR THE FOUNDATION PHASE PRE-SERVICE TEACHERS**

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**ABSTRACT**

My proposed research seeks to ascertain the knowledge legitimated in mathematics methodology curricula for Foundation Phase pre-service teachers. The trajectory of (under)performance, which starts in the Foundation Phase, has been attributed to the poor development of learner's number sense. While there are a multitude of reasons for this, one of the explanations suggests that teachers have insufficient content and pedagogical knowledge to develop learner's number sense. Linked to this explanation are concerns about the teacher education system in South Africa, and the extent to which teacher education programmes are equipping teachers with the necessary knowledge and skills to develop learner’s number sense. Documentary analysis of the mathematics methodology curricula, and interviews with lecturers involved in teaching the number sense component of the curricula will be used to generate the empirical data. I will draw on Legitimate Code Theory and the Mathematics Knowledge for Teaching framework as the explanatory and analytical tools. The findings of this proposed research will be of value to teacher education programmes, particularly in relation to the design of the number sense component of pre-service mathematics methodology curricula.

**INTRODUCTION**

International and national benchmarking tests all confirm that South African learners are underperforming in mathematics (Reddy, 2017). This situation is worse in no-fee paying schools. There are many explanations for poor learner performance, these include: underdeveloped number sense; teachers' inadequate content knowledge and pedagogical knowledge; and inadequate teacher education the research on which this paper is based, attempts to respond to these explanations. The research asks the question: What knowledge and knower structures are legitimated in the number sense component of Foundation Phase pre-service mathematics methodology curricula? Specifically: What knowledge is being privileged in the mathematics methodology curricula and why this might be the case? and What and how knowers are positioned in the mathematics methodology curricula?

**LITERATURE REVIEW**

The research literature reveals two different perspectives to the development of Number Sense: the cognitive science perspective and the mathematics education perspective. The cognitive science domain conceptualises number sense from the neurocognitive, evolutionary and biological factors...
(Gallistel and Gelman, 1992). Number sense is regarded as evolutionary available to pre-linguistic infants and encoded in human memory by a dedicated neural circuit. Through the evolutionary process humans have developed number sense as they adapt to the everyday demands of a numerate society. Dehaene (2008) confirm that our brains are all hardwired in the same way with core knowledge systems enabling learning and development.

By contrast, the mathematics education domain conceptualises number sense from a pedagogic viewpoint while acknowledging that factors such as socioeconomic context, developmental conditions and learning dispositions etc. have an impact on the development of number sense. McIntosh, Reys & Reys (1992) define number sense as a person’s general understanding of number and operations along with the ability and inclination to use this understanding in flexible ways to make mathematical judgments and to develop useful strategies for handling numbers and operations.

THEORETICAL FRAMEWORK

Critical Realism is adopted as an ‘underlabourer’ to this study. It is a philosophical underpinning that provides a nuanced version of a realist ontology and a relativist epistemology (Bhaskar, 1990). As the methodological equivalent of critical realism, this study uses Legitimate Code Theory (LCT) as the explanatory and methodological tool. LCT is a realist sociological framework that views knowledge as both socially produced and objective, in the sense that it has effects (Maton & Moore, 2010). Drawing on the work of Bourdieu, LCT is a fields-based approach; viewing social fields of practice as being relatively autonomous and characterised by their own ways of working, own resources and forms of status (Maton & Chen, 2017).

LCT emerged out of Bernstein’s work, particularly, and of interest to my research, the ‘pedagogic device’. The ‘pedagogic device’ is helpful in analysing the ‘intrinsic grammar’, thus explaining how knowledge is created, distributed and pedagogized (Bernstein, 1990). This process is made up of three separate yet intertwined fields - production, reproduction and recontextualisation. This study will deliberately concentrate on the field of recontextualisation which consists of the sites in which knowledge is selected, (re)arranged and transformed to become accessible to pre-service teachers. This speaks directly to the unit of analysis of this study – Foundation Phase mathematics education curricula in pre-service teacher education.

Although LCT consists of multiple explanatory tools, this study deliberately uses specialisation to establish the way agents and discourse within a field are constructed as special, different or unique and thus deserving of distinction and status (Maton, 2004). Specialisation relates to the bases for differentiating a field from other fields in terms of epistemic relations and social relations. The ‘epistemic relation’ refers to what is being studied and the ‘social relation’ refers to who is studying it (Maton 2000, p. 85).
Specialization codes explain knowledge in the context of knowledge itself and in the context of knowers. The specialization codes include knowledge codes, knower codes, elite codes and relativist codes. Knowledge codes seek to explain the specialized knowledge within intellectual fields. Knower codes explain the legitimate kind of knower. With regards to these codes, I draw on a framework that has been used across the globe, that is, Ball’s MKfT framework. This framework will assist me in ascertaining the knowledge codes legitimated in the PST mathematics method curriculum.

Mathematics Knowledge for Teaching (MKfT)

There is a consensus amongst researchers including Ball et al., (2008) that there is a specific knowledge that is needed to teach mathematics. This knowledge is summarized by Ball et al., (2008) into two categories, that is, Subject Matter Knowledge and Pedagogical Content Knowledge.

The Subject Matter Knowledge category consists of three domains: Common Content Knowledge (CCK), Specialized Content Knowledge (SCK) and Horizon Content Knowledge (HCK). In brief, CCK refers is the knowledge of mathematics that is common to anyone who understands mathematics and is used in daily activities by every citizen, for example calculating costs of groceries and estimation of time. HCK entails the knowledge that allows a teacher to make connections between different math concepts in different grades. SCK refers to a unique degree of understanding mathematical principles that are specific to the teaching and learning mathematics (e.g. being able to identify student errors and knowing how to correct them). This mathematical knowledge is too detailed for any everyday functioning other than teaching.

Pedagogical Content Knowledge consists of the Knowledge of Content and Curriculum (KCC), Knowledge of Content and Students (KCS); Knowledge of Content and Teaching (KCT). KCS entails the awareness of socio-economic, cognitive and other factors that affect learning and teaching mathematics. This is central to knowing how to link content and students. KCT refers to the ability to understand the requirements and demands of content and pedagogy. KCC points to the knowledge of content and the requirements stipulated in curriculum and learning and teaching support materials.

METHODOLOGY

This is a critical realist case study. The data will be drawn from a review of the mathematics methodology curricula from five different South African universities. This research will make use of document analysis to review the curricula, outlines, exam questions, assignments, tests etc. Additionally, I will interview one mathematics methodology lecturer from each institution to consolidate what transpires from the curricula. The data will be coded following the aid of a translation devise to further analyse the data. This study will take into account the typology of Maxwell (2012) to foster validity, thus descriptive validity, interpretive validity and theoretical
validity. This research process will abide with the ethical considerations stipulated in Rhodes University ethics guide and the ethics of the participating institutions.

CONCLUSION

This research will inform curriculum development and improve the teaching/development of number sense. The aforementioned methodological tools will be useful in denoting the legitimated knowledge from the curricula. However, there is a need to devise tools that captures the elusive modalities of mathematics.

REFERENCES


A SYSTEMIC REVIEW OF THE LITERATURE INFORMING THE DEVELOPMENT OF NUMBER SENSE IN PRIMARY MATHEMATICS TEACHING
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ABSTRACT
This paper presents an overview of a systematic review currently being conducted on the literature informing the development of number sense in primary school. The reviewed literature, so far, shows that the approach to number is informed primarily by two perspectives: cognitive science and a mathematics education perspective. This paper analyzes national and international number sense articles accessed via the EBSCOhost database.

INTRODUCTION
The empirical objective of this paper is to provide a systematic review of how number sense is conceptualized in the research literature. The context from which this review emerges is the concern with learners’ poor performance in mathematics in South Africa. Allegedly, research on learners’ developmental trajectory suggests that South African learners’ number sense is not fully developed during the early stage of school and this problem is tied to the poor performance of mathematics in South Africa. There are several explanations for this poor performance including insufficient teacher content and pedagogical knowledge. With that in mind, this paper explores the national and international literature on (i) conceptions of number sense; and (ii) development of number sense in primary schools.

LITERATURE REVIEW
There is a significant level of consensus amongst qualitative and quantitative researchers on the fact that number sense is an elusive concept. The definition and conception of number sense are contested. Although this is the case, this paper adopts Berch’s (2005) categorisation of the number sense into two domains: the cognitive science domain and mathematics education domain. This provides a guide to the review process in which the literature is categorised and analysed according to its emphasis. The research literature is being used by Teacher Education institutions to inform the teaching of primary mathematics and in facilitating the development of number sense.

The cognitive science perspective conceptualises number sense as tied to neurocognitive, evolutionary and biological factors (Gallistel and Gelman, 1992). This perspective considers number sense to be evolutionary available to pre-linguistic infants and encoded in human memory by a
dedicated neural circuit. As such, number sense is innate in that everyone is born with number sense and our brains are ‘wired’ in the same way (Dehaene, 2008). This perspective is much descriptive with special referents to the origins of number sense. This means that this perspective tends to focus on the tangible attributes of number sense.

The Mathematics Education perspective conceptualizes number sense from a pedagogic viewpoint and acknowledges that factors such as socioeconomic context, developmental conditions and learning dispositions etc. have an impact on the development of number sense (McIntosh, Reys & Reys, 1992). This perspective has a broader understanding of number sense, claiming that there are multiple attributes of number sense that include knowledge of numbers and operations, skills, dispositions etc. Its explanation is very prescriptive, it offers means to mathematical performance through developing number sense. Furthermore, the literature on mathematics education can be categorized into the general understanding of number sense, that’s the attributes (Berch, 2005). There is also a plethora of research literature focussing on the challenges of mathematics linked to the lack of number sense (Butterworth, 2005). Another section of the literature focusses on an internalist approach of how to develop number sense and how to teach mathematics (Baker, Bruckheimer and Hegg, 1971).

Although these two perspectives are separate, they both offer an important coverage on the understanding of the elusive concept of number sense and how different institutions are developing it.

**METHODOLOGY**

This is a systematic review of the number sense articles informing the teaching or development of number sense. Specifically, the review focuses on (i) the research literature’s conceptions on number sense; and (ii) the development of primary school children’s number sense. I am in the process of conducting a search for related articles using the EbscoHost mega-database to access these articles. I have selected Academic Search Premier, ERIC, PsychInfo, Psyc Articles and Socio Index as the databases. The initial search used the key words “number sense”, but that yielded 322 articles. A second search used the key words “number sense” and “elementary education”, this yielded 365 articles.

**Way forward**

The way forward will be to continue with the systematic review in order to have a detailed understanding of how number sense is conceptualized and developed in primary schools. I hope this review will be able to inform teacher education institutions mathematics methodology curricula, specifically in promoting pre-service teachers’ competence in developing primary school children’s number sense.
REFERENCES


SCHOOL MATHEMATICS PERFORMANCE: A LONGITUDINAL CASE STUDY

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ABSTRACT

The shortage of longitudinal studies of mathematics (M) performance in South African schools and the bimodal nature of (M) achievement in South African schools demands that both previously disadvantaged and ex-model C schools are researched. The aim of this research is to establish the longitudinal profile of (M) performance of boys attending an ex-Model C, single gender school. Learners’ promotion marks across 8 cohorts from grade 1 to grade 12 (grade 12: 2009-2016) were used. A comparison is made between the change in performance of those who take (M) to grade 12 (n =302) and those who opt for mathematical literacy (ML) (n=160). The effectivity of learners’ (M) performance in lower grades predicting performance in subsequent grades is explored. Data was analysed fitting a Mixed Model for Repeated Measures (MMRM). The MMRM was fitted using Restricted Maximum Likelihood (REML), fitting fixed effects of cohort, grade and grade within a cohort. Findings show a difference in achievement between (M) learners and (ML) learners with the latter set consistently achieving below the former, from grade 1 to grade 12. Primary school performance up to grade 6 is stable across time. The highest (M) mark obtained by all learners is in grade 7, after which the (M) set has a decrease of 25% by grade 11. The decline in the (ML) set is steeper with a 22% drop by grade 9, but an upswing in marks to grade 12. An argument for factors affecting motivation using Self-Determination Theory, the transition to high school and aspects of the curriculum on performance, is made.

The findings of this study could be applied to other ex-Model C schools and inform stakeholders of the impact earlier grades have on subsequent grades, where learners could be more vulnerable as well as assist with subject choices for grade 10.

INTRODUCTION

In South Africa two sectors of schooling exist, the first includes 70-75% of schools, grappling with issues such as poor home environments, English not spoken at home and limited resources (Spaull, 2013a; Reddy & Juan, 2013). The other sector, making up 25-30% of schools in South Africa (Fleisch as cited in Spaull, 2013b), provide a good standard of education (Yamauchi, 2011). The education provided in these two sectors was, and largely still is, worlds apart. This bimodal education system requires that the approach to interpreting data from an ex-Model C school must vary from that used when looking at the previously disadvantaged schools (Spaull, 2013a; ). Spaull (2013a) highlights the need for research that separates the two contrasting groups in the South African education system.
Reddy & Juan (2013) confer, stressing that a disaggregation of achievement scores into categories is essential for meaningful analysis of (M) achievement. Spaull (2013a) adds that “the ‘average’ South African learner does not exist in any meaningful sense” and yet despite these averages being misleading, national and provincial averages are the main measure of performance used in government reports, making research in both these sectors essential.

Primary research question: What is the longitudinal profile of (M) performance of boys attending a South African ex-Model C, single-gender school?

Secondary research questions:
1. How does (M) performance change through the course of schooling for learners who take (M) to grade 12 and for those who do not?
2. How effectively does a learner’s (M) performance in lower grades predict their (M) performance in higher grades?

There appears to be no literature examining the change in (M) performance of a single group of South African learners from grades 1-12. Thus, an ex-model C boys’ urban school with well-archived data was selected for research. This study focuses on the trends in (M) achievement over time and does not attempt to isolate the specific subskills (such as counting or knowledge of fractions). Comparisons in performance over time between (M) and (ML) matriculants is made.

LITERATURE REVIEW

Over time children’s self-perceptions change, affecting how they respond to tasks. In the Foundation phase, learners are generally very optimistic as to their ability to master a skill. Their skill base increases rapidly, driving this expectation of success despite initial failure (Eccles, 1999). This overrated view of themselves provides increased motivation and enthusiasm to tackle tasks. With the onset of puberty, an adolescent experiences increased sensitivity to socioemotional situations (Casey, Duhoux, & Malter Cohen, 2010; Pfeifer et al., 2011). Pfeifer & Peake (2012) on the other hand, consider the establishing of an identity and the need for being part of a group as interrelated. As a child matures into an adolescent, a shift occurs in his self-assessment as he becomes more aware of how he compares to others. This change in perception of self affects a learners’ self-efficacy and self-concept (Eccles & Wigfield, 2002) which both play a role in their development and changes in motivation. Motivation (both extrinsic and intrinsic) in turn influences a learner’s underlying reason for and level of action to achieve an outcome. As children mature and set goals for themselves, motivation is more sustained. This allows self-regulating learners to manage the interplay between what they know, what resources are at their disposal and what deviations may be necessary in order to accomplish their goals. Through this interactive process, they continually make adjustments in order to maximise the chance of succeeding (Winne, 1995). Lemos (as cited in Boekaerts, 1999) considers it characteristic of self-regulated learning that these personal goals give direction and invigorate behaviour.
METHODOLOGY

Two data sets were established allowing a comparison to be made between the change in performance of learners throughout their schooling of those who take M to grade 12 (n = 302) and those who opt for ML (n = 160). The data was analysed fitting a Mixed Model for Repeated Measures (MMRM). The MMRM was fitted using Restricted Maximum Likelihood (REML), fitting fixed effects of cohort, grade and grade within a cohort. Regression analysis was applied to determine the extent to which earlier grades predict subsequent grades.

FINDINGS

In figure 1 below, the performance across 12 years of schooling for the (M) and (ML) sets is shown.

Figure 1: Least Squares Means (LSM) estimate and Standard Errors (SE) of promotion marks (%) per grade for mathematics and mathematical literacy sets

The (M) and (ML) sets followed a similar trend from grade 1 to grade 7. The (ML) set achieved 5-8% lower than the (M) set throughout this period. The performance is stable up to grade 6. The highest mark in (M) for both sets throughout schooling is achieved in grade 7.

In grade 8 there is a steep drop in marks in the (ML) set with the gap between the two sets widening to 13%. Both sets continued a decline in marks to grade 9, when the (M) set has a Least Squares Means (LSM) estimate of 60% and the (ML) set a LSM estimate of 47%. The mathematics set declines
further, reaching its lowest point in grade 11 (LSM estimate = 51%). There is an upswing to 56% in grade 12. In contrast to this, the (ML) set experienced an increase to 66% in grade 10, an increase of 19%. This trend continued and had an LSM estimate of 79% in grade 12.

Correlations between grade 9 and subsequent (M) marks could assist learners making subject choices for grade 10.

CONCLUSION

Primary school performance up to grade 6 was stable with the highest mark achieved in grade 7. A sharp decrease in marks from grades 7 to 9 is evident. ML learners’ marks increased significantly to grade 12, while the M learners’ marks continued a downward trend to grade 11 with an upswing in grade 12. Marks in grades 8-11 could assist with prediction of grade 12 marks.

REFERENCES


THE ETHNOMATHEMATICS OF TINSMITHS IN THE OPTIMIZATION OF TRAYS CYLINDRICAL CANS: A CASE STUDY OF VANDUZI DISTRICT.

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ABSTRACT
This article aimed at understanding the ethnomathematics that tinsmiths use in the optimization of cylindrical trays and cans. The participants were two tinsmiths from Vanduzi district, which is 32 kilometers from the city of Chimoio - Manica province, in the first half of 2018. Literature review, interview and observation were the main methods used, from which the following results and conclusions emerged: The first tinsmith is concerned with maximizing the volume of the tray and he does it by trying. The second does not even know that it is possible to have a tray with maximum volume. Regarding the cylindrical can, the first is concerned with minimizing the sheet metal when making trays; he only lacks the basic non-formal mathematics for this purpose. The second is not interested in how much sheet metal he spends; he associates the volume of the utensil with the price.

Key terms: Ethnomathematics; Tinsmiths; Optimization.

INTRODUCTION

The tinwork, is one of the activities in wish some local knowledge of math may be present, it is one of the professions that has been developed since the colonial era and which ensures guarantees the survival of some Mozambican families.

This work aims to understand the "base of Indigenous Mathematics" that they use to maximize the volumes in the production trays and cylindrical brass without a lid, minimizing the raw material.

Justification
Given the fact that the acquisition of the sheet metals used in tinwork is costly, the study of the Ethnomathematics of tinsmiths in maximizing volumes would help in material saving but producing objects with maximum volumes.

Because Ethnomathematics studies "mathematical traditions that survived colonization and mathematical activities in the daily life of the population, looking for opportunities to incorporate them into the curriculum; cultural elements that can serve as a starting point to practice and perform mathematics in and out of school "(GERDES, 2012: 18), the discovery of such knowledge may be
useful when used as didactic alternative in schools, for some procedures used to teach formal mathematics (academic) do not always help students develop relations between their everyday life and the learnt material.

**Problematisation**

The author of the present work, passed through a tinware when in was taking a walk in Vanduzi district, which is 32 kilometers from the city of Chimoio. The author saw several utensils produced such as trays, pots, buckets, funnels, cylindrical cans, watering cans.

What drew the most attention was the type of sheet metal used to produce the utensils versus the price of the product. The sheet metal used is commonly known as zinc and IBR. It is rectangular, corrugated, 3.5 meters long and 0.8 meters wide and can cost up to 950 MT. According to the tinsmith, each sheet of metal could produce for example 15 cylindrical cans with 10 liters capacity costing 100 MT each.

Looking at the profit obtained and the time spent, there was need to understand whether:

The tinsmith minimizes the expense of the sheet metal used to produce the cylindrical brass of his capacity in liters?

The tinsmith maximizes the volume in the production of a tray whenever he has the same measurements of the sheet metal?

**General objective**

To understand the Ethnomathematics that tinsmiths use in the optimization of trays and cylindrical cans

**Specific objectives**

- To describe the steps used for the production of trays and cylinders;
- To identify the materials used in the production of trays and cylinders;
- Identify geometric objects during the production of trays and cylinders;
- Understand how the tinsmith maximizes the volume of the tray during the production;
- Understand how the tinsmith minimizes waste of sheets during the production of a V liters cylindrical brass without cover.

**METHODOLOGY**

Before the trip to the land where data was collected, there was a period of literature review on the optimization and finding some key terms of the topic.

Given the fact that Ethnomathematics is an ethnographic subject, the research was exploratory in that it did not raise any hypotheses.
The research was developed based on the visit and interview with two tinsmiths who live Vanduzi district. In addition to the interview, the observation was a crucial method for a detailed description of the activities done by tinsmiths, with the help of a notebook and camera.

1. CONCEPTS AND PROTOTYPES MADE BY THE AUTHOR FOR THE STUDY.

As stated D'Ambrosio (1991: 11) “... ETHNOMATHEMATICS is the art or technique that aims to explain, to know, to understand, in different cultural contexts...”.

Tinware- tinsmith shop or establishment where they sell cans, brass objects, tinfoil etc.; bodywork (Dictionary HOUAISS)

**Optimization**

Optimizing is to find the maximum or minimum of a function, that is, to seek the critical points of the function.

**Prototype presented by the author for the maximization of the tray volume.**

From the rectangular sheet of A4 size with the dimensions of 0.3 meters long and 0.2 meters wide intended to produce a tray whose dimensions (length, width and height) give rise to maximum volume. This would serve to compare with produced utensils.

![Image 1 - Issue outline for the production of the tray with maximum volume.](image1.png)

Height: x = 0.04 meters. Length 0.22 meters wide and 0.12 meters.

![Figure 2 - Prototype constructed based on the dimensions found in the calculation.](image2.png)

One of the major goals of this work was to understand whether tinkers could minimize the metal sheet they spend in the production of a V liters cylindrical brass without cover.
An open cylindrical brass of zinc must have the capacity of \( V \) liters. In what dimensions should the deposit be made so that in manufacturing they spend the least amount of metal sheet?

\[
r = \sqrt[3]{\frac{V}{\pi}} \quad h = \frac{V}{\pi^3 \left(\frac{V}{\pi}\right)^2}
\]

2. PRESENTATION AND ANALYSIS

First coppersmith: Jaime Thomas and his son Timothy

Figure 4 - Mr Jaime and his son in full working tinwork.

Question 1: Have you ever thought that these metal sheets of the same size (A4) can produce trays of different volumes? If so, what would you do to produce trays with maximum volumes based on metal sheets of the same size?

"The secret lies in the extension of the cuts in the diagonal. The higher the cut recess, the lower the volume produced tray ".

Image 5 - the same size of zinc producing trays of different volumes in which one of them should be the maximum in the author’s perspective.
Question 2: Given a V liters cylindrical brass. How do you choose the dimensions of it to save the expenses of the metal sheet (raw material) in its production?

"Usually we work with utensils already made, taking the measurements. Here we often produce cans of 10 liters. For the production of a tray that takes 10 liters we need to measure 0.7 meters contour and 0.25 meters high. Back to the question you gave me, the secret is in the height of the tray. For me to save my metal sheet, I have to increase my height to 0.27 meters, keeping the measure contour to 0.7metros ".

The second tinsmith: Ricardo Benedito, 32, 9th grade.

Answer to question 1: "No! The zinzs are the same size and logically they will produce trays of the same volume. What changes will be only the height of each tray."

He was then asked to make two trays of different heights. Then one of them was filled with mealie meal. Pouring the same quantity in the other tray, he personally found out that one of the trays had greater volume than the other.

Answer to question 2: "I just produce cylindrical cans and I am not interest in their volumes. Then stipulate the prices according to the size."
It was hard to tell whether Mr. Ricardo was saving his metal sheet because he was not based on any volume for the production of cans.

**The Ethnomathematics patent in the tray and cylindrical can during the production.**

During the production of a tray and a cylindrical can by the two tinsmiths, it was noted that the following figures: rectangles, circles, parallelepiped (box without lid) and cylinder. These elements can be explored in classes of basic education, showing the student that these figures with the formal nomenclature (cylinder and parallelepiped for example) can be found in our communities, only known by other names (trays and cans).

The production of tray done by the first tinsmith and according to him, he would have the maximum volume. The tray had 0.035 meters height; a measure that does not differ a great deal with the referenced prototype in 2 of this article. This approach can be interpreted through the attempt method he uses to determine the height, "If the diagonal cuts are prolonged, the volume of the tray will be small." Thus the dismissal of the existence of a non-formal mathematics for the explanation of this reasoning.

Regarding the production of the 10 liters cylindrical can (1000cm$^3$) done by the first tinsmith, the dimensions indicated were conducive for the minimization of the expense sheet, and there was a significant difference. Now let us see: making use of the generalized calculations patent in number 2 of this article, we would have:

\[
r = \sqrt[3]{\frac{10l}{\pi}} = \sqrt[3]{\frac{1000}{3.14}} = 6.8 \text{ cm}.
\]

Thus the height would be:

\[
h = \frac{1000}{3.14 \cdot \sqrt{(318.5)^2}} = 6.8 \text{ cm}
\]

According to the data provided by the tinsmith to minimize the metal sheet, the contour was of 70 cm and 27 cm height.

If the lateral area is given by $2\pi rh$, then the contour could simply be defined by $2\pi r$, which would be equal to 2x3, 14x6, 8=42.7 cm.

Making a comparison, the tray height (27cm) is far from the optimal height (6.8cm). The contour of the tray (70cm) is also different 42.7 cm.

Here it is clear that the tinsmith desires to minimize the metal sheet but does not have the knowledge of how to do it.

3. **CONCLUSION**

The first tinsmith is concerned with maximizing the volume of the tray and does it by using an attempt method. The second is not concerned with the maximization of the metal sheet when it comes to
sheets of the same measurements because according to him, two metal sheets of the same size always produce trays of the same size differing only in height.

With regard to the cylindrical can, the first is concerned with the minimization of the metal sheet spent in the production; he only lacks a non-formal mathematical basis for this purpose. The second is not interested in the metal sheet spent; he just associates the utensil size to the price.

4. BIBLIOGRAFIA

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DEVELOPING PRE-SERVICE TEACHERS’ MATHEMATICS DISCOURSE IN THE CONTEXT OF LESSONING STUDY

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ABSTRACT
This paper draws from an ongoing research study which is aimed at exploring how preservice mathematics teachers learn from and with the research-designed tool, The Mathematical Teachers’ Framework (MTF) in a particular context, a ‘lessoning study’- (a model with features of Japanese Lesson study Swedish Learning study). This aim is achieved through the lens of a developing analytical framework based on Wenger’s (1998) notion of meaning and practice within a community of practice (CoP).

BACKGROUND

This study fits largely within the studies on research-designed resources (e.g. Kieran; Tanguay & Solares, 2012). The MTF tool was developed within PD programme in South Africa as a discursive resource, based on identification that there were some key needs and challenges in mathematics teaching in South Africa (Adler & Ronda, 2015). Adler and Ronda (2015) developed the MDI framework to illustrate how a specific object of learning (OoL) can be dealt with, in bringing about opportunities for student learning. The capability that teachers want learners to develop is brought to focus via three key elements of teaching: exemplification; explanatory talk and learner participation as illustrated in the figure 1 below:

The MDI reflects the following key aspects that are reflecting the socio-cultural underpinnings and re-contextualizing of other theoretical resources: Object of learning; examples and tasks; naming and
legitimating; interactional patterns (learner participation). It is these concepts that inform the MTF tool and so are key to teachers’ evolving meaning and practice in and through this study.

In this study I argue for the lessoning study (hybrid of Japanese lesson study and Swedish learning study and adapt these into a South African context) as an alternative platform to work within the research-practice gap. Hence the significance of this study should be understood in that context. From Wenger’s (1998) social learning perspective, I argue for “a lessoning study model” as an instance of a boundary encounter between researchers and teachers; and as a premier space for researchers and teachers, impacting both communities of practice. Kazemi and Hubbard (2008) have questioned the role of researcher in the classroom context. They pleaded for future research to capture the interactions between researchers and teachers as they collaboratively exchange knowledge in a specific context. The main contribution of this study is the development of a framework for describing the process where researchers and teachers gather and share a resource to achieve goals of both communities. Furthermore, this study is highlighting a role of a researcher within a research-practice context and the results of this study will provide insights into preservice mathematics teachers’ learning (through participation in a form of CoP-lessoning study, structured to enhance participation) in relation to use of a research-designed tool-MTF.

METHODOLOGY

Data collection
The group of four teachers and myself (researcher) formed a lessoning study group (Community of Practice-CoP) collaboratively working together on a shared lesson plan for teaching a topic of choice within grade 10 function topic, with the guidance of MTF tool. Through the lessoning study cycles, the CoP members were afforded opportunities to reflect on the best way to handle the objects of learning. The aim of lessoning study model is to create innovative learning environments with a research-designed resource. As such, it is aimed at pooling teachers’ valuable experiences in one or a series of lessons to improve their teaching and learning (Marton & Pang, 2006).

The data was collected from different kinds of instruments (e.g. observations, field notes-researcher’s journals, and teachers’ reflective journals) as they provided different contexts and produced multiple discourses. Three lessoning study cycles were conducted. There were three sessions in each cycle of the lessoning study: 1. The lesson planning; 2. Teaching, observing, debriefing (reflective discussions); and 3. Re-teaching. The lessoning study cycle is depicted in the figure 2 below:
In this study teacher learning is described in terms of Wenger’s (1998) concept of negotiation of meaning: duality between reification and participation. Secondly, teacher learning is also described in terms of how a research designed tool-MTF is used in the lessoning study activities/practices, (i.e. in terms of reflections and keeping focus on Ool-critical aspects of the OoL).

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>TEACHER LEARNING</th>
<th>STAGES OF L/S</th>
<th>MARKERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What meanings do teachers attach to MTF?</td>
<td><strong>Negotiation of meaning</strong></td>
<td>Lesson planning</td>
<td>Reification -participation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>teaching</td>
<td>Reification -participation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reflective discussion</td>
<td>Reification -participation</td>
</tr>
<tr>
<td>2. How can teacher learning be described in terms of teachers’ practices?</td>
<td><strong>Focus on the OoL</strong></td>
<td>Lesson planning</td>
<td>Potential CA (intended OoL)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>teaching</td>
<td>Discovered CA (enacted OoL)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reflective discussion</td>
<td>Real CA (Existed OoL)</td>
</tr>
<tr>
<td></td>
<td><strong>Reflections</strong></td>
<td>Lesson planning</td>
<td>Reflection-for-practice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Teaching</td>
<td>Reflection-in-practice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reflective discussion</td>
<td>Reflection-on-practice</td>
</tr>
</tbody>
</table>

During the coding stage I have found studies concerning teacher learning helpful, which consists of the following: negotiation of meaning with a reified tool (Wenger, 1998; Pepin et.al, 2013), teacher learning in a learning study context-Focus on object of learning (Runesson, 2013; Pillay, 2013), and teacher learning in a lesson study context-Teacher reflection (Posthuma, 2012). The ideas suggested in these studies were used to generate codes in the transcripts.

**CONCLUDING REMARKS**

This study is at the stage of generating codes and refining them. In the presentation I will present some preliminary data analysis and findings of the first cycle of the lessoning study.

**ACKNOWLEDGEMENTS**

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**REFERENCES**


INVESTIGATING MEDIATION STRATEGIES USED BY EARLY YEARS MATHEMATICS TEACHERS IN MALAWI

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ABSTRACT
This short paper presents a proposed doctoral study on mediation strategies used by mathematics teachers in early years of primary schooling in Malawi. The study is guided by the Mediating Primary Mathematics (MPM) framework developed by Venkat & Askew (2018) which helps to determine what is available to learn in a lesson by examining the extent to which the teacher works with tasks/examples, artifacts, inscriptions, and talk/gesture. Data will be collected through lesson observations and video-stimulated recall interviews, and will be analysed using the key elements of MPM framework.

BACKGROUND
One of the major perplexing problems in the history of mathematics education has been to understand why learners fail mathematics despite the provision of seemingly adequate teaching and learning resources. This puzzle has been of major interest by various researchers and theorists throughout the centuries (Sfard 2008). For children in Malawi, the problem of lack of understanding Mathematics is often observed from the perpetual low scores attained by learners during standardised national examinations. Malawian learners also perform comparably lower than other countries in standardised assessments in mathematics and numeracy. Surprisingly tests of teacher knowledge from SAQMEQ I and SAQMEC II showed that Malawian teachers possessed sufficient content knowledge to teach standards (i.e grades) 1 to 6 (Ravishankar, El- Kogali, Sankar, Tanaka, & Rakoto-Tiana, 2016). As such, the low performance of learners in SAQMEQ tests may not wholly be attributed to teachers’ lack of content knowledge. Some of the problems that hinder learners understanding of mathematics and numeracy as they advance to senior classes can be attributed to the strategies used by the teachers in the early years of primary school. Oftentimes, the idea of “number” might be introduced to children differently from what they encounter in their everyday life, thus alienating ‘school mathematics’ from actual ‘mathematics’ (Frobisher, 1999; Boaler, 2016). As noted by Boaler (2016) the wide gulf between school mathematics and real mathematics is the heart of many problems that have led to a dislike of the subject, eventually making people disengage their minds in mathematics despite efforts of the teacher.

The effect of the approaches used by teachers in early years is noticed through learners’ mathematics performance as they advance from lower to senior primary school. In Malawi, the diminishing trend
in mathematics performance as learners move to upper primary school classes was noted in one baseline study on learning achievement of standards 3 and 7 learners conducted by the Malawi Institute of Education in 2009 (Maganga, Mwale, Mapondera, & Saka, 2010). In the study, the mean score in numeracy and mathematics for standard 3 learners was comparably higher (24.76%) than other subjects (such as 5.79% for English). Surprisingly, the learners’ standard 7 performance in mathematics (14.76%) was lower than other subjects (14.87% for English). It is the teacher’s task, therefore, to maintain learners’ motivation and achievement in mathematics, which gradually declines as the children advance to senior sections of the primary school. This study, therefore, seeks to explore the mediation strategies used by mathematics teachers in early years of schooling in Malawi to gain an insight into what is made available to learn through the observed practices. The findings will inform policy and practice related to the teaching of early years mathematics in Malawi and similar contexts. The findings will also contribute to pedagogical content knowledge of mathematics teachers for early years of primary schooling. Documentation and dissemination of the best practices learnt during the study will also inform teacher educators and policy makers who are responsible providing support to teachers through continuous professional development.

The study will seek to answer the following main question:

- *How do Malawian teachers of mathematics in early years mediate the delivery of mathematical instruction in the classroom?*

The main question will be answered through the following subsidiary questions:

- *How do teachers in early years work with tasks/examples during lessons?*
- *How do mathematics teachers use artifacts during early years of primary school?*
- *In what ways do teachers use inscriptions to represent mathematical processes in early years?*
- *What talk/gestures do teachers use to generate solutions to problems, make mathematical connection, and advance learning connections?*

**THEORETICAL FRAMEWORK**

In this study, the classroom teaching/learning process will be understood using the Mediating Primary Mathematics (MPM) framework (Venkat & Askew, 2018). The framework focuses on the nature of the mathematics that is made available to learn in the classroom and enables a detailed exploration of the quality of primary mathematics instruction. The MPM framework is grounded on Vygotskian concept of mediation as the major requirement for learning. To understand mediation, the authors adopted the sociocultural perspective, viewing the teacher’s role as the sole mediating agent in the classroom. They argue that defining the quality of mathematical instruction by adopting the foreign concept of learner-centeredness has often been unsuccessful in sub-Saharan Africa. This idea of adopting culturally situated norms of pedagogy as opposed to reforms advocating learner centred pedagogy largely agrees with the issues extensively discussed by Tabulawa (2013) on failure of pedagogical reforms in sub-Saharan Africa. Sociocultural theory deemed useful in determining the goals in mathematical instruction, as well the sociocultural materials and practices for mediation. The
MPM framework identified four overarching means of mediation (called strands): Tasks/examples, artifacts, inscriptions, talk/gesture. The framework provides an analytical tool for assessing the extent to which the mathematics teacher works with each of the four strands of mediation.

PROPOSED METHODOLOGY

Since the main aim of the study is to understand the complex issue of teaching mathematics to young children, it is exploratory in nature. The research will adopt a multi-method qualitative case study design in which data collection through lesson observation will be followed up with interviews with teachers, and document analysis. Purposive sampling will be used to ensure selection of participants based on exemplary performance. A paradigmatic case (Palys, 2008; Flyvbjerg, 2006) of one primary school will be chosen as an exemplar of a well performing school based on learners’ performance in standardised national examinations. One class will be chosen at each level (standards 1 to 4) for lesson observation, making a total of 16 classes. One participating teacher will be selected under each class based on their work-related performance. A series of mathematics lessons will be observed under addition of numbers which spans across the four classes. Each lesson will be video recorded for detailed analysis. Video simulated recall interviews will be done with each of the four teachers to seek clarification on the choices made during the lesson.

Data analysis

Recorded videos of lessons will be analysed using MPM’s tool for lesson analysis (Venkat & Askew, 2018). The categories for each of the MPM’s 4 key components of mediation will be encoded using the codes specified in the framework. This will be followed by summative judgments based on levels determined using the framework’s specified criteria. In each case the analysis will be done for one object of learning. For each of the four classes, the focus will be on ‘addition of numbers. For interviews, thematic data analysis will be used for identifying recurrent themes in transcribed data.

Piloting

The study will be piloted at a rural school where four lessons of one teacher will be observed and analysed. Preliminary findings from the pilot study will be shared during the conference to solicit inputs on how to shape the main study further.

REFERENCES


**Acknowledgement**

This study will be carried out with support from Norwegian Programme for Capacity Development in Higher Education and Research for Development (NORHED) programme through the Strengthening Numeracy in Early Years through Capacity Development of Teachers project based at the University of Malawi in collaboration with the University of Stavanger.
South Africa’s challenges with mathematics education are well documented and known. There is increasing acknowledgement that intervention is needed in the early primary grades. In particular, a range of studies point to the need for nudging both early primary teachers and learners away from concrete counting-based strategies towards more efficient and flexible strategies for calculating and working with number (e.g., adding and subtracting). The same authors have pointed out that the early grades’ Annual National Assessments (ANAs) tended not to address weak number sense. These tests were abandoned in 2016. Among the various criticisms was that they did little to encourage the teaching of number sense and the focus on correct answers led to acceptance of counting based strategies, (and often, highly inefficient unit counting based strategies), thus perpetuating rather than addressing problems of progression (Xxx, Yyy & others).

South Africa’s national curriculum policy includes that Mathematics should “develop mental processes that enhance logical and critical thinking, accuracy and problem solving that will contribute in decision making” (DBE, 2011, 8-9). The document includes reference to a range of basic facts (fluencies) that learners should know instantly (such as adding one, two or ten to a number; knowing number bonds to ten) as well as a range of calculation strategies that support efficient and flexible working (such as ‘bridging through 10’ and ‘doubling and halving’). Thus, the ‘gap’ would appear to be in translation from the curriculum through to assessment, with at least some of the ideas represented as important for number sense represented in the curriculum documents. This gap provided the impetus for a national initiative developed as a partnership between the two South African Numeracy Chairs (the authors of this paper), the Department of Basic Education, and a range of professional and academic bodies with interest in primary mathematics research-based development. The initiative was grounded in diagnostic assessments for use in Grade 3 classrooms with associated professional development focused on supporting teachers to understand the relationship between using such fluencies and strategies to move students beyond one to one concrete methods of calculation.

The Foundation Phase diagnostic assessment investigation emerged from this context and was led by the two South African Numeracy Chair who are mandated to search for ways forward to the challenges of mathematics teaching and learning in primary schools in South Africa. The Chairs, located in two separate provinces have worked closely together since 2011 (see Xxx & Yyy (2017) for...
Given widespread acknowledgement that assessment influences practice, absence of attention to number sense that underlies fluent, flexible and strategic mental and written working in previous ANAs was seen as problematic. Furthermore, we noted that to shift teacher practice on a national scale national assessment practices would need to foreground number sense and non-concrete strategies. Our representative from the national DBE noted that there was policy level interest in diagnostic assessments that could be administered with an orientation grounded in feedback loops into teaching and learning. Thus, following our week of deliberations we decided we should investigate a possible format for the design a series of diagnostic assessments and reasoning chains to support the teachers and learners to move beyond concrete methods of calculation to using awareness of number relations and structure in ways that promote effective efficient calculation.

Following our 2017 SAARMSTE plenary panel presentation of the diagnostic intervention model with Mark Chatty (DBE) and Busi Goba (AMESA), we focus, in this presentation, on the results of the first pilot interventions of the first in a series of diagnostic assessments focused on promoting the teaching and learning of calculation strategies for Grade 3 learners in South Africa. The series of assessments, consisting of short classroom tests addressing calculation strategies such as bridging through ten, jump strategies and doubling and halving, top and tail sets of reasoning chains for teacher use in eight ten-minute mental mathematics sessions designed to develop learner fluency in related skills and the focal strategy. Three groups of assessment items are included for each strategy, namely: rapid recall, strategic calculating and strategic thinking items. The post-test assessments are then used as to gauge any improvements in student learning related to the strategy in focus. Initial trials were conducted for the ‘bridging through ten’ strategy in six classes across two provinces in South Africa. Results, summarized later, show positive learner outcomes.

A socio-constructivist perspective broadly guided our deliberations and the design of our diagnostic assessments and reasoning chains. Kilpatrick, Swafford & Findell’s (2001) model of five strands of mathematical proficiency (namely: conceptual understanding, procedural fluency, adaptive reasoning, strategic competence and productive disposition) and the inter dependence of these strands broadly informed our thinking. Askew (2012) extends this work by noting that learner understanding is made visible through what he describes as the visible ‘actions’ of proficiency, seen through the lenses of fluencies, problem-solving and reasoning. In terms of designing assessment items, our work was guided by seminal assessment work developed in England and Australia by our
two international participants namely Mike Askew and Bob Wright (respectively) and their colleagues (Askew et al. (1997); Askew (2012); Wright, Martland and Stafford, (2006); Wright, et al. (2006)).

In our presentation we report on the findings of our formal pilot across six classrooms in two provinces. Post-test outcomes point to pleasing gains in both provinces. In the Eastern Cape, gains were seen across all three of our item categories (rapid recall, strategic calculating and strategic thinking); in Gauteng, a small drop in performance in the strategic calculating category was outweighed by substantial increases in all of the other categories. Table 1 provides a summary of the data:

Table 1: Eastern Cape and Gauteng Grade 2/3 outcomes

<table>
<thead>
<tr>
<th></th>
<th>Rapid Recall (20 items: 2 minutes)</th>
<th>Strategic Calculating (5 items: 1 minute)</th>
<th>Strategic Thinking (5 items: 1 minute)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>MeanPre %</td>
<td>MeanPost %</td>
<td>MeanPre %</td>
</tr>
<tr>
<td>Eastern Cape</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Grade 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(n=65)</td>
<td>26.7</td>
<td>40.7</td>
<td>11.7</td>
</tr>
<tr>
<td>Grade 2</td>
<td>31.2</td>
<td>56.4</td>
<td>10.3</td>
</tr>
<tr>
<td>(n=30)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gauteng</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade 3</td>
<td>56.3</td>
<td>75.3</td>
<td>37.6</td>
</tr>
<tr>
<td>(n=134)</td>
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</tbody>
</table>

Feedback from the teachers involved also suggested positive experiences of working with the reasoning chains. Our findings suggest that the diagnostic test-let/reasoning chain activity model can contribute to improvements in performance in ways that support the development of number sense. Our recommendation in moving forward would be a broader and more nationally representative DBE-led trial of the test-lets and reasoning chain activities that have been developed. Our sense is that broader and more representative trials are needed to decide the robustness of the results above prior to considering the feasibility for use at a national level.

Acknowledgements

Thanks to our broader team and in particular to Dr Lawan Abdulhamid and Sameera Hansa for assistance with the data collection and collation, and Dr Lynn Bowie and Dr Pam Vale who worked with us on the data collection, collation and analysis. Also thanks to the DBE and the NRF for their support of this work.

REFERENCES


COMPUTATIONS IN NAMIBIAN PRIMARY SCHOOLS: Exploring the Need for Mental Arithmetic Skills
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ABSTRACT
This paper is an extract from a bigger study which sought to explore the incorporation of mental arithmetic in primary schools. Informed by the Critical Mathematics Education theory, the study explored the state of mathematics education in primary schools by looking at the computation strategies used by teachers and learners during classroom mathematics sessions at senior primary Grades. The study sampled 10 schools in the Oshana region in Namibia. Senior primary teachers at these schools were observed. The computation procedures used by both teachers and learners were recorded. At times, the researcher took snapshots of the teachers’ and learner’s workings. The preliminary findings suggest low level of numeracy in learners. The teachers mostly practiced standard algorithms even when learners displayed difficulties in comprehending these strategies. The study, therefore, recommends an intervention for teachers to enable a variety of computation strategies in the classroom as opposed to rigidly adhering to the use of standard algorithms. The study further recommends thorough emphasis of mental computation strategies in mathematics education programmes at teachers training institutions.

Keywords: Computation strategies, Mathematics, Mental Computation, Numeracy, Performance.

SUBMISSION DOCUMENT

The development of numeracy or mathematical literacy is mainly held as the purpose for studying mathematics in primary schools. Numeracy is the ability to use mathematical ideas effectively to make sense of the world. It involves understanding notations and techniques as well as being able to draw knowledge of particular contexts in deciding to use mathematical approaches (Westerford, 2008). As such, schools should not only equip learners to develop competence and confidence in computational skills, they should also develop a much broader competency, one that include an ability to apply understanding of numbers, space and measurement in realistic situations.

Senior primary mathematics aim to develop learners’ functional numeracy and mathematical thinking in order to be able to apply mathematics in everyday life among other aims (Ministry of Education, 2015:1). However, Namibia was recorded to have the highest proportion of functional innumeracy (47.69%) in a comparative study by Spaull (2011) in which he compared the Southern and Eastern Africa Consortium for Monitoring Education Quality [SACMEQ] III results of Botswana,
Mozambique, Namibia and South Africa. Moreover, the senior primary learners have been performing below average in the mathematics Standardised Achievement Tests [SATs] (Mutuku, 2015) which indicates learners cannot do computations mentally. This study therefore sought to address the following two questions: (1) What computation strategies do primary school mathematics teachers and learners use in their mathematical operations? (2) Are these methods helping to enhance numeracy development? These questions guided the study.

LITERATURE REVIEW

The Namibian Mathematics Curriculum for senior primary supports the acquisition of mental computation skills through the development of thinking strategies across the senior primary phase. The curriculum states that:

“Learners are expected to use mental methods and paper-and-pencil methods sensibly and appropriately” (Ministry of Education, 2015: 2).

Ministry of Education (2015) further emphasises that senior primary learners are not allowed to use calculators and that teachers must place emphasis on mental arithmetic strategies to develop the learners’ awareness of number and number sense. Learners are required to compute exact answers and make precise approximations mentally. Before learners exit senior primary phase, they should possess a variety of strategies of mental computations. It is important for teachers to recognize these strategies, develop them and improve them over time with regular practice. It is thus peculiar that teachers incorporate mental computation strategies in their lessons daily.

Mental arithmetic in this study refers to the development and use of strategies for calculating mentally (Swan & Sparrow, 2001). It is more than the mere recalling of basic numerical facts such as the mastery of multiplication tables. It is mainly concerned with building computation strategies. This study embraces the position that learners develop a range of mental strategies by being exposed to rich situations requiring them to think, relate and build up a computational strategy.

Mental arithmetic is a fundamental element of children’s basic education and every adult’s daily life. Basic arithmetic knowledge (i.e. being able to compute simple addition, subtraction, multiplication and division problems as well as making accurate approximations) is a prevalent necessity of everyday living and it provides the foundation for more advanced mathematical skills central to all modern scientific disciplines. Computing mentally is a viable alternative to a calculator and the development of mental computation procedures contributes to the formation of powerful mathematical thinking strategies (Morgan, 1999).

The mathematical skills, knowledge, concepts and processes, enable the individuals to investigate, model, and interpret numerical and spatial relationships and patterns that exist in the world (Ministry of Education, 2009; Iyambo, 2010). The mental arithmetic skills allow an individual to make quick computations and estimations of daily live calculation problems. Education systems in many
countries around the world, (McIntosh, 2004), has a view that mental arithmetic mainly means a recall of simple addition, subtraction or multiplication facts. Such is still the practice in Namibia and South Africa, (Ministry of Education 2015; South African Department of Basic Education, [DBE], 2011). There seem to be less emphasis on the experiences that encourage discussion and learning and more on activities that focus on testing in primary schools. The need is now drawn to focus computational tools as well as a decreased emphasis on the traditional algorithms. Learning has now focused attention on learner autonomy and the use of invented strategies as methods for developing basic facts and computational procedures. Hence, there is a need for a study that explores computational strategies practiced in primary schools and how these strategies incorporate mental arithmetic.

THEORETICAL FRAMEWORK

The study used the critical mathematics philosophy as a theoretical framework. The term ‘critical’ in connection with mathematics education is used by Frankenstein (1983), after she coined it from Freire’s critical consciousness, and developed a critical mathematics literacy programme which sought to enhance the mathematical confidence of adult students through a collaborative approach where social issues are directly related with the learning of mathematics. Frankenstein defined critical mathematics as “understanding mathematics in a way that will enable you to use that knowledge to cut through the assumptions which are taken for granted about how the society is structured and to act from more informed choices about those structures and processes” (p.42). Research in critical mathematics pedagogy questions the ‘taken-for-granted’ structures in education and understand them in order to critically act on these.

About 10 years after Frankenstein coined the term critical mathematics education, Skovsmose published his book Towards a philosophy of critical mathematics education, in which he introduced the theoretical sparks for a critical mathematics education utilising the critical theory developed by the Frankfurt School. Critical mathematics education is the education that addresses the conflicts in society by uncovering inequalities and oppression of whatever kind (Skovsmose, 1994) having in mind that the learning of mathematics can empower or disempower the lives of the individual learners. Addressing the critical role of mathematics in society entails an understanding of the risks and uncertainties that mathematics and societal progress conveys. Learners should be presented with situations in which mathematics may format the way they understand and behave in reality.

Dominant in the Skovsmose (1994) ideas is the concept of mathemacy. He described mathemacy as a proficiency in handling mathematical procedures and appropriately applying these in a variety of situations. The mathemacy concept is crucial to mathematics curriculums in terms of its content and pedagogical approaches in the schools. Mathemacy is comprised of reflections through critical enquiries (Cotton, 2012). These are enquiries on the mathematical processes and interactions in the schools. In line with the notion of mathemacy, this study sought to explore computation strategies used in primary schools looking at the interactions between the teachers and learners in the senior primary classrooms.
METHODOLOGY

Embedded in the critical mathematics theory, the study was of a qualitative design in its efforts to explore and understand the classroom practices of the senior primary teachers and learners. A qualitative paradigm entails the collection, analysis and interpretation of comprehensive narrative and visual data to gain insights into a particular phenomenon of interest (Gay, Mills & Airasian, 2013). The study conveniently sampled 10 out of the 91 schools that offer senior phase in the Oshana region – Northern Namibia. The sampling was based on the accessibility to the schools requiring minimal resources in terms of time and transport costs.

Observations were the method of data collection. In pursuit to explore the strategies practiced by senior primary classrooms, the observations allowed the researcher access to interactional settings to understand situations in their contexts. At each of the ten schools, one mathematics teacher and his/her learners were observed for a day. Detailed notes of behaviours, events, patterns, interactions in the classroom settings were recorded (Simpson & Tuson, 2003). The observations were unstructured. The researcher took notes of the teaching strategies of the teachers and how mental arithmetic was incorporated in solving problems.

The learners’ responses to verbal questions and to problems on the chalkboard as well as responses in their note books were recorded. The researcher took video clips and snapshots of learners’ work which were useful for further analysis. These observations gave a picture of the state of mathematics classroom practices at senior primary schools.

The learners (and their parents) were assured that the results from the tests were to be used for the sole purpose of the study and parental consent was obtained. No possible chances of learner victimisation based on their responses existed. The pictures captured during observation sessions were cleared of learners’ faces and/or personal items they could be identified with. The next section presents the results of the study.

RESULTS

The teachers and learners’ classroom practices were observed and several cases of interest were recorded. The recordings range from teachers’ instructions, strategies used in solving examples, teachers’ solutions, learners’ responses and learners’ solutions. The following are examples of the findings from several classrooms:

1. Calculate 10% discount on a bicycle that is marked N$2050. What is the new price?

The problem was written by the teacher on the chalkboard. A learner was called to the chalkboard to solve the problem. Figure 1 contains a snapshot of her working.
Learner’s working: \( \frac{10\% \times 2050}{100} = \frac{205}{2} \)

Here, the teacher stepped in and told the learners that the answer is not \( \frac{205}{2} \) but N\$205. The teacher did not point out where the learner went wrong or how the correct answer was to be obtained. Instead, he went on to work out the new price as:

The teacher approached the problem using a standard algorithm of subtracting in columns with digits aligned according to place values. He further advised learners to always ‘borrow’ when the digit above is less than the digit below. The class did not an alternative to obtaining the difference 2050 – 205.

2. Calculate 12% discount on a CD that is marked for N\$ 128.00? What is the new price?

The second problem is also based on percentage discount. The teacher wrote the problem on the chalkboard and called up a learner to solve it.
The learner wrote: \[ \frac{12}{100} \times 128 = \frac{12}{100} \times 128 = \frac{12}{25} \times 32 = \frac{432}{25} \]

It can be seen in learner’s working that he simplified correctly but he wrongly worked out \(12 \times 32 = 432\). The learner did not show his workings and the teacher did not ask how he arrived to a wrong product. Instead, the teacher told the class that the product of \(12 \times 32\) is 384 and not 432. He then asked the learner (who was still standing by the chalkboard) to use long division and divide 384 by 25. The learner got \(384 \div 25 = 15\) and looking at the teacher, the following conversation arose:

Teacher: You are not done. Does 25 go exactly 15 times into 384? Learner: No. There is remainder 9.
Teacher: What do you do to nine when dividing in long division? Learner: 9 divided by 25 is impossible.
Teacher: Class! What do we do? Class: (goes quite)
Teacher: What if we add a 0 to nine?
Learner: Oh, we get 90!

The learner then continued with long division and got a value of the discount as N\$ 15.36. The teacher did not explain why a zero should be added to 9 to give 90.

**What is the new price?**

The teacher called up another learner to the chalkboard and she solves in a rectangular array format (a standard algorithm).

\[
\begin{array}{cccc}
1 & 2 & 8 & 7 \\
1 & 5 & 3 & 6
\end{array}
\]

\[=
1 & 1 & 2 & 6 & 4
\]

The standard algorithm involving trading was used. It appears the practice of standard algorithms were the regular approach to solving problems.
3. A car dealer sells a second-hand car for N$ 45 600. He makes a loss of N$4400 on the car. Express the loss as a percentage.

Loss of 4400 at a selling price of 45 600 implies value of the car is 50 000. Teacher took on to solve the problem as follows:

\[
\text{% loss} = \frac{\text{loss}}{\text{cost price}} \times 100 = \frac{4400}{50000} \times 100
\]

Teacher shifted to the other side of the board to do long division and got the answer 8.8%. It appears long division was commonly practiced to arrive to answers. At this stage the concept of simplifying using common factors seemed forgotten.

4. Work out: 2.136 ÷ 1.2

This lesson was about dividing decimals. The teacher taught the ‘moving decimal’ method - the approach where the decimal points is moved a required number of steps until the divisor became a whole number. The same number of steps are also moved on the dividend to keep the ratio the same.

The learners were then later given to work out the problem 2.136 ÷ 1.2. Figure 4 shows the pictures of learners’ workings.

*Figure 4: Learners working out the division: 2.136 ÷ 1.2.*
The first learner in the collage missed the ‘moving decimal point’ concept. The rest of the pictures in the collage illustrates how senior primary learners cope with the long division strategy. When presented with two- or three-digit values to multiply or divide, learners resorted to drawing tallies or counters on pieces of papers to aid computation.

5. Cost price = N$360, Profit = N$18, what is the percentage profit?
The class was working on percentage profit. The teacher wrote down an example on the chalkboard for the class. Cost price = N$360 and profit = N$18, what is the percentage profit? Worth noting here is the structure of the question and how it lacks context.

Figure 4 contains the teachers’ solutions:

![Figure 4: Teachers' calculations of the percentage profit.](image)

The teacher simplified to get \( \frac{18}{360} \times 5 \) which is readily equal to 5 but, instead, the teacher went on to multiply the numerators. The whole process became longer as it involved long division to simplify \( \frac{18}{360} \) and then multiply \( 18 \times 5 \) via the repeated addition.

6. Work out 6.4 ÷ 0.4
The teacher was teaching division of decimals. The first example given by the teacher was 6.4 divided by 0.4. The teacher told learners to ‘move the decimal point’ until the divisor is a whole number. The same number of ‘moves’ were also to be performed on the dividend to keep the figures in the same ratio.
That gave \( 6.4 \div 0.4 = \frac{64}{4} \).
Then the teacher worked out the problem as in Figure 5.
The teacher divided 64 by 4 and got 16. Then he told learners that since the original values where 6.4 ÷ 0.4, the answer should have a decimal point ‘between the two digits’. That is incorrect. The answer 16 was correct as a final answer. Standard algorithms seems to be performed by both teachers and learners as series of steps with less numerical reasoning.

The results points to a high practice of standard algorithms in the primary schools. The mental computation strategies are lacking. Teachers make use of the standard algorithms to solve examples. The teachers also urge learners to make use of standard algorithms such as aligning numbers in columns for multiplications and long division.

**DISCUSSION**

This section discusses the results in the order of the examples presented.

1. Calculate 10% discount on a bicycle that is marked N$2050. What is the new price?

An alternative, mental arithmetic strategy would be: \( \frac{10}{100} \times 2050 = 205 \)

The learners at the senior primary level are supposed to be in possession of simplifying skills (MoE, 2015). There are also several mental computation strategies teachers need to explore in their classrooms instead of restricting learners to examples of standard algorithms. An alternative to the used standard algorithm is the ‘break up and bridging’ as: 2050 – 205 = 2000 + 50 – 200 – 5

\[ = 2000 – 200 + 50 – 5 \]
2. Calculate 12% discount on a CD that is marked for N$ 128.00, what is the new price?

The teachers should be guiding learners appropriately. Problems like \(12 \times 32 = 432\) should not be left unattended as these may persist. Moreover, the referrals of learners to standard algorithms such as long division need to be stopped as several steps during these standard algorithms seem to be performed without reasoning. For example, the teacher did not explain why a 0 should be added to a 9 during the long division. Learners should be allowed to exercise various ways of dividing.

3. A car dealer sells a second hand car for N$ 45 600. He makes a loss of N$4400 on the car. Express the loss as a percentage.

The teacher arrived to a step where he had to work out \(\frac{4400}{500}\) and right away moved to long division. This seemed to indicate that the concepts of common factors and simplifying gets forgotten during other topics of mathematics. The fraction, \(\frac{4400}{500}\), simplifies to 44 which can be worked out as \(\frac{40}{5} + \frac{4}{5} = 8 \frac{4}{5}\%\) as an alternative approach to long division. The teachers seemed to only practice long division whenever a ratio is to be computed.

4. Work out: \(2.136 \div 1.2\).

The learners’ working in Figure 3 are an indication of the difficulties faced by learners while performing multiplication and/or division. When learners face difficulties with standard algorithms such as column multiplication and long division, they tend to use hand-drawn manipulatives or tallies to help them get to answers. The use of hand-drawn manipulatives (see Figure 3) may serve some students well with simple calculations, however, learners are likely to face problems once they move on to more complex computations (Callingham, 2005).

5. Cost price = N$360, Profit = N$18, what is the percentage profit?

The structure of the problem seems not to be well formulated and the problem lacks context. The teachers should be contextualising problems so that mathematics makes meaning with in the learners’ world. It would seem also that the teachers’ solution was unnecessarily too long. It appears as if the teachers also perform calculations via standard algorithms without thorough reasoning. A learner who might make a mistake at any of these steps will be marked incompetent in percentage profit while a learner possibly has a problem with multiplication or long division.

6. Work out \(6.4 \div 0.4\)
The teachers’ working points to another case where ‘rules’ of algorithms are seemingly memorised by teachers and performed without reasoning. For instance, an alternative to long division would be a mental computation strategy involving distribution over addition as:

\[
\frac{64}{4} = \frac{40}{4} + \frac{20}{4} + \frac{4}{4} = 10 + 5 + 1 = 16.
\]

There seems to be no efforts of exposing learners to several other methods to give them a variety of options when it comes to computations. However, the Namibian mathematics curriculum expects senior primary teachers to place emphasis on the mental arithmetic strategies to develop the learners’ awareness of numbers and number sense (Ministry of Education [MoE], 2015:1). The development of mental arithmetic strategy is necessary will be flexible at operations well aware there exists more than one way to arrive at the solution to a problem (Swan & Sparrow, 2001). The results also illustrate how learners face problems with long division. An examiner in these cases is likely to conclude that learners have problems with “percentages/money topics” while they are failing due to a standard algorithm strategy they have not mastered well (Graven, Venkat, Westaway, & Tshesane, 2013). The results of this study agree with the recommendations by Graven, Venkat, Westaway, & Tshesane (2013) that to enhance numeracy, instructions and assessment should focus on the development of strategies and not just end results.

CONCLUSIONS & RECOMMENDATIONS

Following from the teachers’ practices which are evident in the examples we have considered above, we are of the view that teachers mostly practiced standard algorithms even when learners displayed difficulties in comprehending these strategies. The idea of developing mental arithmetic strategies is to produce flexible thinkers (Spaull, 2011) as learners gain more insight into the properties of the number system (Swan & Sparrow, 2001). Learners’ perspectives (and their voices) are discouraged and silenced by teachers’ tendency to resorting to the use of standard algorithmic procedures. Learners’ imaginations are discouraged in contrast to a critical mathematics education perspective. The study, therefore, recommends that senior primary mathematics teachers must be enabled to use a variety of computation strategies in the classroom as opposed to rigidly adhering to standard algorithms through teacher development and initial teacher education programmes. Mental computation strategies in mathematics education need to be an integral component of senior primary mathematics teacher education programmes at teacher training institutions.

Acknowledgements

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COLLECTIVE TEACHER EFFICACY: Its Impact on Curriculum Delivery in High Schools with Similar Quintile Ratings (Socio-Economical Contexts)

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ABSTRACT
This case study comprises quantitative data investigating the impact of collective teacher efficacy on the views of teachers in terms of curriculum delivery in poorly resourced high schools with similar socio-economic contexts in East London, South Africa. The collective efficacy data include aspects such as the Curriculum, Attainment, Learning and Teaching, Support, Ethos, Resources and Management. The study is premised on two hypotheses; the first hypothesis suggests that there is no significant difference between collective efficacies among teachers of schools with similar socio-economic contexts. The second hypothesis states that collective efficacy has a significant impact on curriculum delivery even if the socio-economic contexts are the same. 76 teachers were selected using purposive sampling, responding to a collective efficacy questionnaire on issues relating to the teaching and learning. The study uses descriptive and inferential statistics and the sample comprised three high schools with similar quintile ratings. The data analysis includes descriptive statistics using measures of central tendency and measures of dispersion. Analysis of Variance (ANOVA) is used to measure statistical significance to find statistically significant differences between the collective efficacies among teachers, and statistically significant differences between collective efficacy of teachers and curriculum delivery. The findings suggest that there are significant differences between collective efficacies of teachers within and between schools even if the socio-economic contexts are similar. The data suggest that the collective efficacy of teachers affects views of curriculum delivery, even if the socio-economic contexts are similar. Recommendations suggest further research in positive collective efficacy beliefs among teachers that could lead to effective curriculum delivery.

Keywords: Efficacy, Poverty, Quintile, Resources, Equal, Capacity

INTRODUCTION

Resource audits conducted in South African schools confirm massive inequality of resources between affluent and previously disadvantaged schools as the main cause for academic underperformance and dropout rates of learners (Ndhlovu, 2012).

In order to address the massive inequality, the basic education sector a White Paper 2 was published by the Department of Education (1996), and designed to guide education policy for the coming years...
Curriculum 2005 (C2005) was the result of this government-driven change (Aldous 2004, p. 65). Further curriculum changes occurred in South Africa since then, notably Curriculum 2005 (C2005), the Revised National Curriculum Statement (RNCS), the National Curriculum (NCS) and currently the Curriculum and Assessment Policy Statement (CAPS). These curriculum changes demanded a high level of commitment and competence from teachers for its implementation.

The government introduced quintiles to address the inequality in public schools. The quintile ratings of schools are based on a model that categorises schools in bands according to their socio-economic surroundings. Each Provincial Education Department assigns a poverty score to each school based on the relative poverty score of the community. The variables include household or individual income of the community in the school’s attachment area, dependency ratio (the proportion of income earners to people who are dependent), or unemployment rates and level of education in the community. Table 1 refers to the schools that are divided from quintile one (poorest) to quintile five (least poor).

### Table 1: 2017 National Poverty Distribution Table

<table>
<thead>
<tr>
<th>Quintiles</th>
<th>% 1 poorest</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern Cape</td>
<td>27.3</td>
<td>24.7</td>
<td>19.6</td>
<td>17.0</td>
<td>11.4</td>
<td>100%</td>
</tr>
<tr>
<td>Free State</td>
<td>20.5</td>
<td>20.9</td>
<td>22.4</td>
<td>20.8</td>
<td>15.4</td>
<td>100%</td>
</tr>
<tr>
<td>Gauteng</td>
<td>14.1</td>
<td>14.7</td>
<td>17.9</td>
<td>21.9</td>
<td>31.4</td>
<td>100%</td>
</tr>
<tr>
<td>Kwazulu-Natal</td>
<td>22.1</td>
<td>23.2</td>
<td>20.2</td>
<td>18.7</td>
<td>15.8</td>
<td>100%</td>
</tr>
<tr>
<td>Limpopo</td>
<td>28.2</td>
<td>24.6</td>
<td>24.2</td>
<td>14.9</td>
<td>8.0</td>
<td>100%</td>
</tr>
<tr>
<td>Mpumalanga</td>
<td>23.1</td>
<td>24.1</td>
<td>21.5</td>
<td>17.7</td>
<td>13.5</td>
<td>100%</td>
</tr>
<tr>
<td>Northern Cape</td>
<td>21.5</td>
<td>19.3</td>
<td>20.7</td>
<td>21.4</td>
<td>17.1</td>
<td>100%</td>
</tr>
<tr>
<td>North West</td>
<td>25.6</td>
<td>22.3</td>
<td>20.8</td>
<td>17.6</td>
<td>13.7</td>
<td>100%</td>
</tr>
<tr>
<td>Western Cape</td>
<td>8.6</td>
<td>13.3</td>
<td>18.4</td>
<td>28.0</td>
<td>31.7</td>
<td>100%</td>
</tr>
<tr>
<td>South Africa</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>100%</td>
</tr>
</tbody>
</table>

(Source: Department of Basic Education, 2017)

Recommendations were made to delink the school allocation from the quintile raking into only two broad bands (Table 2) namely no fee schools (quintiles 1, 2 and 3) and fee schools (quintiles 4 and 5) (DBE, 2017).

### Table 2: 2017 No fee schools and no fee learners

<table>
<thead>
<tr>
<th>Provincial Education</th>
<th>No fee schools</th>
<th>% No fee schools</th>
<th>No fee learners</th>
<th>% No fee learners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern Cape</td>
<td>5 205</td>
<td>95.17%</td>
<td>1 578 131</td>
<td>83.12%</td>
</tr>
<tr>
<td>Free State</td>
<td>1 004</td>
<td>82.70%</td>
<td>575 582</td>
<td>85.69%</td>
</tr>
<tr>
<td>Gauteng</td>
<td>1 396</td>
<td>67.02%</td>
<td>1 463 721</td>
<td>71.45%</td>
</tr>
<tr>
<td>Kwazulu-Natal</td>
<td>4 964</td>
<td>84.21%</td>
<td>2 059 153</td>
<td>73.33%</td>
</tr>
<tr>
<td>Limpopo</td>
<td>3 726</td>
<td>96.35%</td>
<td>1 645 519</td>
<td>96.41%</td>
</tr>
</tbody>
</table>
The sample schools have quintile 3 ratings. The national government has decided that the minimum adequate allocation is R1 243 per learner per annum in quintile 1 to 3, R623 in quintile 4 and R215 in quintile 5 as illustrated in the Table 3 below.

### Table 3: 2018 per learner allocation

<table>
<thead>
<tr>
<th>Provincial Education Department (PED)</th>
<th>Quintile 1-3</th>
<th>Quintile 4</th>
<th>Quintile 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>National threshold</td>
<td>R1 243</td>
<td>R623</td>
<td>R215</td>
</tr>
<tr>
<td>Eastern Cape</td>
<td>1 316</td>
<td>660</td>
<td>228</td>
</tr>
<tr>
<td>Free State</td>
<td>1 316</td>
<td>660</td>
<td>240</td>
</tr>
<tr>
<td>Gauteng</td>
<td>1 316</td>
<td>660</td>
<td>660</td>
</tr>
<tr>
<td>KwaZulu-Natal</td>
<td>955</td>
<td>522</td>
<td>179</td>
</tr>
<tr>
<td>Limpopo</td>
<td>1 316</td>
<td>660</td>
<td>228</td>
</tr>
<tr>
<td>Mpumalanga</td>
<td>1 285</td>
<td>650</td>
<td>226</td>
</tr>
<tr>
<td>Northern Cape</td>
<td>1 243</td>
<td>778</td>
<td>366</td>
</tr>
<tr>
<td>North West</td>
<td>1 316</td>
<td>660</td>
<td>228</td>
</tr>
<tr>
<td>Western Cape</td>
<td>1 316</td>
<td>1 055</td>
<td>390</td>
</tr>
</tbody>
</table>

The Eastern Cape is one of the worst performance provinces when comparing national pass rates for Grade 12. The quintile 3 rating comprises 19.6% of the total learner population in the Eastern Cape, which impact on the learner attainment rates (refer to Table 1).

The curriculum delivery takes place in the classroom by the subject teacher. The effective delivery of the curriculum is impacted upon by how teachers’ perceptions are shaped by what they see and what they experience.

**Objectives of the Study**

The objective of this study is to investigate the impact of collective teacher efficacy on teachers’ views of curriculum delivery in schools with similar socio-economic contexts.

**Review of the Literature**

The focus of teacher efficacy research has been on teacher’s self-efficacy, and not on collective teacher efficacy (Klassen, Tze, Betts & Gordon, 2010, p. 25). Goddard (2002, p. 467) labelled collective efficacy as a ‘neglected construct’ in educational research and called for further research examining the links between collective teacher efficacy and student achievement.
The role of teachers, with their own dynamics to academic access within the school environment, have been an object of interest for several researchers (Bandura, 1986, 1993; Klassen, Tze, Betts & Gordon, 2010). One such institutional characteristic associated with academic access and development of students is collective teacher efficacy (Bandura, 1993, 1997).

Collective teacher efficacy is the “perception that a group of teachers have about the ability of influencing the academic performance of their students” (Ramos, Silva, Potes, Fernandez & Nina, 2014, p. 179). Collective efficacy as a construct is based on Social Cognitive Theory (Bandura, 1977, 1986, 1997) which explains how people exert some control over their own lives.

When teachers operate in different teaching environments, they have different experiences in terms of preparation, induction, professional development and expectations for student behaviour and achievement (Yeom & Ginsberg, 2007). This paper addresses how collective experiences of teachers impact on their views of curriculum delivery in similar socio-economic contexts.

Academic access and development of learners takes place within the enactment of a particular curriculum. The Curriculum and Assessment Policy Statement (CAPS) (DBE, 2010) is implemented by all the teachers in South African public schools.

METHODOLOGY

Research approach
The research approach resides within the positivist paradigm. The data collection and analysis methods include only quantitative data and address issues of validity and reliability.

Research design
This case study uses a survey research design. This research is exploratory in nature in acquiring new insights into a phenomenon to formulate a more precise problem or to develop a hypothesis.

Population
The population for this study includes all high school teachers teaching in quintile 3 schools in the East London District which is 791 teachers at the time.

Sample
Three high schools are from previously disadvantaged communities in the East London Education District, Eastern Cape Province, South Africa where 76 teachers were surveyed. The schools have quintile 3 accreditation and are no fee schools. These schools are in communities that face challenges of illiteracy, unemployment, and poverty, lack running clean water, electricity and proper sanitation.
Equal quintile status schools ensure that teaching, learning and assessment takes place in similar socio-economic contexts facing similar financial, resource and teacher: learner ratio challenges.

**Sampling technique**
The sampling technique is purposive sampling; the sample selection is based on knowledge of the population (Babbie, 2004, p.183). The site selection includes three secondary schools with quintile 3 ratings in East London. These schools have similar social, political and economic disparities.

Teachers (n=76) were selected namely School A (n=24), School B (n=23) and School C (n=29). These teachers were selected across different learning areas, teaching qualifications, experience, and different post levels.

**Ethical Issues**
The ethics guidelines include two aspects, namely: the relationship to practice of science (professional ethics) and the relationship to the subjects (research participants) of science. The principles and guidelines of the Belmont Report (1979) were adhered to throughout the research.

**Data Gathering Instrument**
**Questionnaire**
A Likert scale questionnaire (1 to 5) was used to collect numerical information regarding seven collective efficacy sub-categories of all the teachers in the sample schools. The teachers responded to 66 statements. Numerical values were equating to different responses (1= strongly disagree, 2= disagree, 3= uncertain, 4= agree and 5= strongly agree).

The collective efficacies probed include sub-categories such as *Curriculum, Attainment, Learning and Teaching, Support, Ethos, Resources and Management*. The Curriculum category include indicators such as the *structure of the curriculum, quality of learning areas/subjects and the quality of teachers planning*. The only indicator under Attainment is attainment in learning areas. Learning and Teaching include indicators such as *quality of the teaching process, quality of the teaching process, meeting learner’s needs, assessment and communication with parents*. The Support category includes indicators such as *personal and social development, quality of curricular and vocational guidance and effectiveness of learner support*. The Ethos category includes indicators such as *ethos, partnership with parents and the School Governing Body (SGB), links with other schools, agencies, employers and the community*. The Resources category includes indicators such as *provision of resources, organisation and use of resources and space, provision of staff, staff development and appraisal and school management and finance*. The Management, Leadership and Management category include indicators such as *self-evaluation, effectiveness of leadership and effectiveness of promoted staff and senior teachers*.

**Research Question**
Does collective teacher efficacy have a significant impact on teachers’ views of curriculum delivery in high schools with similar socio-economic contexts?

**Hypotheses**

This study is based on the following hypotheses, namely:

Hypothesis 1: There is no significant difference between collective efficacies among teachers and their views of curriculum delivery in high schools with similar socio-economic contexts

Hypothesis 2: Collective efficacy has a significant impact on curriculum delivery even if the socio-economic contexts are the same.

**RESULTS**

**Collective Efficacy**

The total efficacy mean scores for all the teachers (n=76) of the three schools are shown in table 4. The highest mean total efficacy score was recorded at School C (223) followed by School A (217). The teachers of School B were ranked the lowest with a mean total efficacy score of 197. Table 4: Total mean efficacy (eff) scores of teachers at the sample schools (n=76)

<table>
<thead>
<tr>
<th>School</th>
<th>Total eff mean</th>
<th>Total eff number</th>
<th>Total eff Std dev</th>
<th>Total eff min</th>
<th>Total eff max</th>
<th>Total eff low quart</th>
<th>Total eff median</th>
<th>Total eff up quart</th>
</tr>
</thead>
<tbody>
<tr>
<td>School A</td>
<td>217.29</td>
<td>24</td>
<td>36.38</td>
<td>137</td>
<td>263</td>
<td>191.0</td>
<td>219.50</td>
<td>249.0</td>
</tr>
<tr>
<td>School B</td>
<td>196.96</td>
<td>23</td>
<td>32.33</td>
<td>137</td>
<td>264</td>
<td>170.0</td>
<td>182.0</td>
<td>223.0</td>
</tr>
<tr>
<td>School C</td>
<td>223.0</td>
<td>29</td>
<td>33.11</td>
<td>110</td>
<td>260</td>
<td>215.0</td>
<td>232.0</td>
<td>244.0</td>
</tr>
<tr>
<td>All Groups</td>
<td>213.32</td>
<td>76</td>
<td>35.28</td>
<td>110</td>
<td>264</td>
<td>181.0</td>
<td>221.50</td>
<td>243.50</td>
</tr>
</tbody>
</table>

The median efficacy score, minimum as well as maximum scores and standard deviation are shown as a ‘box and whisker’ plots in figure 1.

*Figure 1: Box and whisker plots of the median total collective efficacy scores (n=76)*
The grouped mean scores for the three schools indicate the highest collective efficacy mean score (55.40) for ‘Learning and Teaching’, while the lowest mean score was for ‘Attainment’ (6.40). The mean scores for ‘Curriculum’, ‘Support’, ‘Ethos’ and ‘Management’ range between 22 and 37 as indicated below in Table 5.

### Table 5: Mean collective efficacy scores for the three schools

<table>
<thead>
<tr>
<th>Efficacy categories</th>
<th>Valid n</th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curriculum</td>
<td>76</td>
<td>22.77632</td>
<td>13.00000</td>
<td>33.00000</td>
<td>4.380559</td>
</tr>
<tr>
<td>Attainment</td>
<td>76</td>
<td>6.36842</td>
<td>2.00000</td>
<td>9.00000</td>
<td>1.477314</td>
</tr>
<tr>
<td>Learn &amp; Teach</td>
<td>76</td>
<td>55.39474</td>
<td>35.00000</td>
<td>74.00000</td>
<td>8.262492</td>
</tr>
<tr>
<td>Support</td>
<td>76</td>
<td>32.69737</td>
<td>3.00000</td>
<td>49.00000</td>
<td>8.096122</td>
</tr>
<tr>
<td>Ethos</td>
<td>76</td>
<td>36.81579</td>
<td>0.00000</td>
<td>49.00000</td>
<td>7.743747</td>
</tr>
<tr>
<td>Resources</td>
<td>76</td>
<td>36.89474</td>
<td>0.00000</td>
<td>52.00000</td>
<td>9.982089</td>
</tr>
<tr>
<td>Management</td>
<td>76</td>
<td>22.36842</td>
<td>9.00000</td>
<td>33.00000</td>
<td>5.613893</td>
</tr>
</tbody>
</table>

**Efficacy categories**

Analysis of variance (ANOVA) revealed that there are statistically significant differences between the mean scores of the schools for Curriculum (p=0.0001; p< 0.05)), Attainment (p=0.0305; p< 0.05), Support (p=0.0391; p< 0.05) and Management (p=0.0029; p< 0.05).

The application of the Sheffe’ test revealed that School B (scored statistically lower than School A (p=0.0007; p< 0.05) and School C (p=0.0006; p< 0.05) in terms of category ‘Curriculum’. The application of the Scheffe’ test to the data generated in the ‘Attainment’ category revealed that School B scored lower than School A and School C at a level considered to be ‘weakly statistically significant’, i.e. at 90% level of confidence (p=0.0727 and p=0.0615 respectively.

Further comparison of the means using the linear contrast test reveal a statistically significant difference at 95% level of confidence between the attainment scores of the teachers at School B and School A (p=0.023; p< 0.05 ) and the teachers in School A and School C (p=0.019; p< 0.05). This information is illustrated in Table 6.

### Table 6: Linear contrast test of the attainment category of all the teachers (n=76)

<table>
<thead>
<tr>
<th>Contrast Estimates (School eff data)</th>
<th>Dependent variable: Attainment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimate</td>
<td>Std. Error</td>
</tr>
<tr>
<td>CNTRST 1</td>
<td>0.971</td>
</tr>
<tr>
<td>CNTRST 2</td>
<td>0.960</td>
</tr>
</tbody>
</table>
The descriptive summary of curriculum efficacies (Table 7) reveals that nearly 40% of the teachers of School B disagreed with the statement on the questionnaire, as opposed to only 4% and 7% for School A and School C respectively.

Table 7: Table of percentage responses to the curriculum question per sample school

<table>
<thead>
<tr>
<th></th>
<th>School</th>
<th>Curriculum category</th>
<th>Curriculum category</th>
<th>Curriculum category</th>
<th>Row</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Count</strong></td>
<td>School A</td>
<td>15</td>
<td>8</td>
<td>1</td>
<td>24</td>
</tr>
<tr>
<td><strong>Row Percent</strong></td>
<td>School A</td>
<td>62.5%</td>
<td>33.3%</td>
<td>4.2%</td>
<td></td>
</tr>
<tr>
<td><strong>Count</strong></td>
<td>School B</td>
<td>4</td>
<td>10</td>
<td>9</td>
<td>23</td>
</tr>
<tr>
<td><strong>Row Percent</strong></td>
<td>School B</td>
<td>17.4%</td>
<td>43.5%</td>
<td>39.1%</td>
<td></td>
</tr>
<tr>
<td><strong>Count</strong></td>
<td>School C</td>
<td>20</td>
<td>7</td>
<td>2</td>
<td>29</td>
</tr>
<tr>
<td><strong>Row Percent</strong></td>
<td>School C</td>
<td>69.0%</td>
<td>24.1%</td>
<td>6.9%</td>
<td></td>
</tr>
<tr>
<td><strong>Count</strong></td>
<td>All Groups</td>
<td>39</td>
<td>25</td>
<td>12</td>
<td>76</td>
</tr>
</tbody>
</table>

Table 7 illustrates the data as an interaction plot graph of the three schools.

Figure 2: Interaction plot of all the teachers (n=76) versus curriculum scores

Statistical degree of confidence in the results by using ANOVA suggests that they are not due to chance. Statistical significance also means that results have or warrant a theoretical explanation as shown in Table 8.

Table 8: ANOVA for the six collective teacher efficacy categories
Four categories namely Curriculum (p=0.0001; p< 0.05), Attainment (p=0.0305; p< 0.05), Support (p=0.0391; p< 0.05) and Management (p=0.0029; p< 0.05) have shown acceptable consistency for statistical significance (p< 0.05; 95% confidence), which has shown significant differences in the collective efficacy beliefs of teachers.

Statistical significance has set levels or cut-off points for rejecting the null hypothesis. The cut-off point is set at p< 0.05 and that has been achieved for the curriculum category as shown in Table 8. The curriculum category on the collective questionnaire is measured at p=0.0001 (p< 0.05) coupled with the mean scores and box and whisker plot show that collective efficacy has a significant impact on curriculum delivery even if the socio-economic contexts are the same.

**VALIDITY AND RELIABILITY**

This questionnaire was used in previous research at Keele University, England and was adapted to suite the objectives of this study.

The reliability of the sub-scales was calculated with Cronbach’s alpha. and is presented in Table 5. The Cronbach alpha coefficient, according to Cohen, Manion and Morrison (2007, p.506) is a measure of internal consistency among multi-item scales, which ranges between 0 and 1. Cohen et al. (2007, p.506) suggest the following reliability levels: less than 0.60 as unacceptably low reliability, 0.60 – 0.69 as marginally reliable, 0.70 – 0.79 as reliable, 0.80 – 0.90 as highly reliable and greater than 0.90 as very reliable. Six of the seven categories had high reliability with Cronbach’s alpha coefficients between 0.777 and 0.914, except for the category Attainment, with unacceptably low reliability with Cronbach alpha coefficient of 0.410. This could be attributed to only two statements in this category. The mean inter-item correlation of the two items for the sub-scale Attainment was 0.260, which was low. This suggests a weak relationship between the two items in the sub-scale that would imply caution when reporting the findings of the scale.
Table 5: Cronbach’s Alpha scores of the collective efficacy categories

<table>
<thead>
<tr>
<th>Collective Efficacy Categories</th>
<th>Cronbach’s Alpha</th>
<th>Cronbach’s Alpha Based on Standardized Items</th>
<th>No of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curriculum</td>
<td>0.777</td>
<td>0.781</td>
<td>7</td>
</tr>
<tr>
<td>Attainment</td>
<td>0.410</td>
<td>0.412</td>
<td>2</td>
</tr>
<tr>
<td>Teaching and Learning</td>
<td>0.850</td>
<td>0.857</td>
<td>16</td>
</tr>
<tr>
<td>Support for Learners</td>
<td>0.914</td>
<td>0.915</td>
<td>10</td>
</tr>
<tr>
<td>Ethos</td>
<td>0.894</td>
<td>0.899</td>
<td>11</td>
</tr>
<tr>
<td>Resources</td>
<td>0.896</td>
<td>0.896</td>
<td>13</td>
</tr>
<tr>
<td>Management</td>
<td>0.900</td>
<td>0.903</td>
<td>7</td>
</tr>
</tbody>
</table>

DISCUSSION OF FINDINGS

Hypothesis 1

ANOVA of the mean responses per school for total efficacy were significant at 95% level of confidence (p=0.0222; p< 0.05 ), as shown in Table 6.

Table 6: ANOVA for total efficacy

| Analysis of Variance (School eff data) Marked effects are significant at p < .05000 |
|-----------------------------------------|---------------------------------|---------------------------------|-------------|
| SS | df   | MS    | SS | Df error | MS error | F   | P       |
|------------------------------|---------------------------------|---------------------------------|-------------|
| Total efficacy              | 9254.5                          | 1                               | 4627.25     | 84115.9 | 73     | 4.0158 | 0.0222 |

A Scheffe’ test on the data revealed a statistically significant difference between the scores of the teachers at School B and School C (p=0.0275; p< 0.05). There is no statistically significant difference between the total efficacy scores of the teachers at School B and School A (p=0.1288), a figure approaching a ‘weakly statistically significant’ position, i.e. at 90% level of confidence). There is also no statistically significant difference (p=0.8309) between the teachers’ total efficacy scores at School A and School C, as shown in table 7.

Table 7: Scheffe’ test p-value of total efficacy scores of all the teachers (n=76)

| Scheffe Test: Variable: total eff (School eff data) Marked differences are significant at p < .05000 |
|------------------------------------------------------------------------------------------|---------------------------------|---------|---------|
| {1}                                                                       | {2}       | {3}     |
| School A {1}                                                               | 0.128886 | 0.830930 |
| School B {2}                                                               | 0.128886 | 0.027531 |
| School C {3}                                                               | 0.830930 | 0.027531 |

Analysis of the data using linear contrast techniques gave a p-value of p=0.044 for the difference in the teachers’ collective efficacy mean scores between School A and School B. Further analysis gave a
p-value of $p=0.008$ between School B and School C, which indicates statistically significant differences between the mean efficacy scores of these schools at the 95% and 99% levels of confidence respectively. The data analysis suggests that the hypothesis 1 is not supported, suggesting that there is a significant difference between collective efficacies among teachers of schools with similar socio-economic contexts.

**Hypothesis 2**

Statistical analysis in the Curriculum category of all the teachers ($n=76$) have shown that there are statistically significant differences ($p<0.05$) in the three sample schools, as shown in Table 8.

*Table 8: Scheffe’ test p-value of the Curriculum category of the teachers ($n=76$)*

<table>
<thead>
<tr>
<th>School</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>School A</td>
<td>0.000742</td>
<td>0.000742</td>
<td>0.991701</td>
</tr>
<tr>
<td>School B</td>
<td></td>
<td>0.000625</td>
<td></td>
</tr>
<tr>
<td>School C</td>
<td>0.991701</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

These responses show consistency with the measure of dispersion in the collective efficacy category as illustrated in the box and whisker plot (Figure 1), with the median scores for School C at the highest, followed by School A and lastly by School B.

Further analysis of the curriculum question per sample school have shown ‘agree responses’ (in table 2) of School C to be to be the highest at 69%, followed by School C at 63% of School A and a low 17% of School B. The interaction plot (Figure 2) gives a visual perspective of low frequencies of the curriculum category of the all the teachers ($n=76$).

The data in the curriculum category are consistent with the data in the collective efficacy category. The data suggest that collective efficacy has a significant impact on views of curriculum delivery even if the socio-economic contexts are the same. Hypothesis 2 is therefore upheld and supported.

**CONCLUDING REMARKS**

Effective delivery of the curriculum is influenced by the availability of resources coupled with teacher/learner dynamics inside and outside the classroom. The data suggest that collective efficacy are a greater determinant of curriculum delivery than socio-economic contexts.

**Recommendations**

Further research is required to establish what triggers positive collective teacher efficacy beliefs among teachers, especially by incorporating best practices in challenging teaching and learning environments.
REFERENCES


"HOMO FABER" IN THE MAKERSPACE OF EARLY GRADES PEDAGOGY: How Student Teachers Make Sense of Tools

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¹University of Johannesburg; ²Funda UJabule School
ehenning@uj.ac.za

ABSTRACT
The research question that guided a study by a mentor teacher at a practicum school pertained to how student teachers learn to make and use teaching tools for foundation phase classrooms. The authors argue that the ‘making’ of tools for teaching should be emphasised in pre-service teacher education and blended with how children can participate in making and designing such tools - thereby creating ‘makerspaces’ in the classroom. The paper reports on a study of a sample of student teachers’ learning to make and use tools for foundation phase mathematics teaching. The findings show that although the students could design and make attractive and potentially usable tools with little expense, they were not (yet) able to implement the tools for children’s learning of mathematics.

Keywords: makerspace, early grades, learning material, student teachers, mathematical concepts

INTRODUCTION: MAKING SPACE FOR USABLE TOOLS

The study on which we report in this paper is about the use and making of tools for pedagogical purposes in the teaching of mathematics in the foundation phase. Teachers of young children regularly use material teaching aids as mediational artefacts in their classrooms. This is more so in mathematics teaching, where teachers are encouraged to use concrete objects as ‘manipulatives’ – a term emphasised by Piaget (1971). How teachers use the tools is often intuitive and the effect is not always clear. When primary school student teachers learn to make and use such artefacts, they often mimic existing ones and fail to reflect on the mediational value of the artefacts, drawing largely on their ‘apprenticeship of observation’ (Lortie, 1975). It is here that the problem of this study is situated.

The primary researcher in this inquiry (Ntsoane, 2018) set out to capture how university students in a foundation phase teacher education programme learn to design, make, and use such tools, arguing that it requires specialized skills to conceptualize and to produce teaching tools – and that it warrants a close-up inquiry. She argued that the use of such tools, furthermore, requires careful planning, taking cognisance of child learning and conceptual development (Henning & Ragpot, 2015) and of pedagogical craftsmanship, to foresee the usability of the tools.
The researcher is a mentor teacher and also head of the foundation phase department at a school with a strong focus on pre-service teacher education practicum. A part of her work is to mentor (Rowley, 1999; Gratch, 1998) student teachers in the teaching of early grade mathematics. Such mentor teachers are briefed to attend to specific aspects of student apprenticeship in pedagogical content knowledge (PCK) (Sothayapetch, Lavonen & Juuti, 2013:85), integrating their knowledge of the curriculum of the foundation phase, their skills of teaching, and their knowledge of the young learners in their context. In the case of making concrete/material teaching tools, mentor teachers at the research site of this study work with groups of students who make pedagogical artefacts that they can add to their teacher toolkit. The work of the researcher can be likened to what is currently referred to as work in pedagogical makerspaces. These ‘spaces’ for pre-service teachers in the context of this study are decidedly low-tech, using recycled materials and natural objects, much like the teacher who was interviewed on a ‘makerspace’ blog recently:

Laser cutters, robots, 3D printers: when people talk about educational makerspaces, images of expensive, high-tech gadgetry comes to mind. In Colleen Graves’ library, they make use of a much cheaper resource. “It’s trash,” she said. “But don’t call it that.” (https://hechingerreport.org/teachers-share-tips-on-making-makerspaces-accessible-to-all/)

No material is viewed as ‘trash’ at the school where this study was conducted. Rather, in the use of materials to create and to recreate materials of different kinds, as researchers we see the student teachers as makers, much as Hannah Arendt (Arendt, 1958) articulated the concept of Homo faber as human tool-maker. Arndt argued that humans who ‘fabricate’ material means to ‘control’ the environment. We refer to her view because we would argue that student teachers need to take cognisance of how children can be partners in making the artefacts that are used to teach them. If Arendt’s view holds, then young learners can be regarded not only as ‘thinking’ people (Homo sapiens) but also as ‘making’ people (Homo faber), with their attraction to design and playful creation (as Homo ludens) awarded some ‘maker’ space in classrooms.

Our view is that every classroom could be a ‘makerspace’ of some kind and children should have the opportunity to ‘control’ some of their learning by being free to express themselves in design and by being learner-makers. In other words, we would say that children sometimes need to create these learning artefacts themselves, using any available material, including (and especially) natural objects.

We propose that student teachers should be prepared for teaching various topics in the mathematics curriculum with this principle in mind: Learners need to be co-developers of instructional tools. We believe that young children are makers of ideational- and material tools to teach themselves and each other, as Vygotsky proposed (Vygotsky, 1933/1978) in the theory of semiotic mediation that he propounded.

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5 See Lev Vygotsky’s treatise for play and ‘making’ (Vygotsky, 1933)
**Apprentices of tool-design tools in classrooms**

In an investigation into student teachers’ uptake of the mentor teacher’s coaching and advisement about teaching tools, we utilised an epistemological model of *design and creation*, as formulated by Thomas and Brown (2009, 2011), to situate tool-making conceptually (Thomas & Brown, 2009:1-2). The construct of student teachers’ learning in a specific mentorship programme is further framed by the *cognitive apprenticeship* model as described by Collins, Brown and Holm (1991), Rogoff (1990), John (20130, Grossman (1991), Dennen & Burner, 2008) and Collins, Brown and Newman (1989). Aligned by these two models, we regard pre-service teacher education as an apprenticeship. We invoke the (Drew et al., 3008) models specifically for investigating tool-making for learning and teaching purposes. We do this with the aim of foregrounding how learners can be participatory tool-makers and how student teachers can be trained to guide them in learning mathematics.

During the early grades, children learn many mathematical concepts through concrete manipulatives and demonstration materials (Drew et al., 2007). In practice, as a foundation phase teacher in a teaching school, the primary researcher has witnessed much repetition (and copying) in the making of such teaching tools by student teachers. She seldom comes across tools that truly exemplify the pedagogical content knowledge (PCK) of teachers, as formulated by Shulman (1987:5). Such tools would exemplify the integration of students’ knowledge of children’s early conceptual development in mathematics as, for example, described by Fritz, Ehler and Balzer (2013:40) about numeracy development. In a country with a limited public budget, it is necessary for teachers to be self-sufficient and to be able to improvise teaching tools and to integrate learners’ inherent ability to *make, play and think* in tandem.

The study was conceptualised with the research question that guided the study, addressing a two-sided issue about the making and using of educational tools for the classroom: How is the Thomas and Brown (2009) epistemological model exemplified in tools student’s teachers design and make and how do students act as apprentices of tool design and creation with the mentor teacher?

**The thinking, making and playing child**

Teachers in the foundation phase mathematics classroom often rely on concrete objects for effective lesson presentation, assuming that this type of playful engagement with manipulatives is the assured bridge to understanding number concepts and number relations. In studies on tool-use in childhood, however, many questions have arisen. From the later work of Piaget (Piaget et al., 1978) it is evident that the use of concrete tools is not guaranteed to be the bridge to understanding. Piaget et al. (1978: Preface) argue that artificial tools themselves are not the source of “intelligence (understanding) and that *Homo faber* as the maker of tools has a good chance to understand the symbolic meaning. We have witnessed how children make their thinking visible with clay and with drawings, for instance. And we looked for some evidence in human development through the ages to help us understand the role of tools.
We came across the work of Lancy (2017), who gives an account of children’s tool-use through the ages. In an aptly titled article, he argues, along the same lines as Essertier (1927, in Piaget et al., 1978)) and Piaget et al. (1978), proposing that *Homo faber juvenalis*, as tool makers/users learned through imitative play and tool-making. He concludes that this is how they (the young) have imitated and played since the evolvement of *Homo sapiens*, while discovering their environment and its artefacts, intersecting with their social and cognitive development. Importantly, Vygotsky (1933), in an analysis of play as ‘leading’ developmental modality, concludes, similarly. In his classic model of human activity, he introduced the theory of tools/artefacts and signs (such as language) that mediate all activity of humans (Vygotsky, 1978). We suggest that a learning-, tool-using/making child engages in the playful, imaginative activity of making thinking visible, or, as Vygotsky (1978, 1933) put it, ‘externalising’ thinking.

![Diagram: The activity of making and/or using an artefact to make thinking visible](image)

We argue that teachers should keep in mind that the tool itself is not the source of knowledge, but the way in which the tool is used or *made* by a child is the learning opportunity. This means that teachers need to be examples of good tool-use and tool design, because children learn by imitation of activity. We would like to also add that student teachers, as apprentices, likewise learn from mentor teachers. A learner who uses a tool is also a *thinking* person and when imagination is activated, there is an element of *play* (Meltzhoff, 2002).

Through teaching tools, teachers must afford learners the proper opportunities to engage creatively and critically with the lesson topic, but also to see the opportunities for ‘ludic’ symbols (Piaget, 1951) to be activated, or play that is symbolic and in which imaging and imagination is foregrounded. Here Piaget argues that *practical make-believe* (for fun and enjoyment) is substituted by *symbolic make-believe* in which play is, actually, quite serious. In other words, the imagination takes over and the
play is not only for pleasure but to imaginatively solve a problem (Piaget, 1951). In spontaneous children’s play this is evident when children ‘play out’ frustration. In the classroom this natural ability can be harnessed for learning and solving problems.

PARTICIPATORY INQUIRY

The study on which we report in this paper was designed to utilise ethnographic tools to provide a description of students’ “way of life” (Wolcott, 1994) in an aspect of their work during the apprenticeship programme at the school. The study is thus a case inquiry (Yin, 2013; Stake, 2013) with the construct as a ‘bounded system’. The study also has ethnographic qualities, because the inquiry describes the way people do things in everyday practice in a specific setting and as a defined group (Wolcott, 1994; Henning, Van Rensburg & Smit, 2004).

Data was collected from scheduled logbook entries of the mentor teacher/researcher and the students as well as video recordings of lessons and audio recordings of focus group discussions/interviews about lessons. In addition, teaching tools of the selected sample of participants were analysed according to criteria of the epistemological model (Thomas and Brown, 2009). The participatory researcher also observed three other mentor teachers and conducted interviews with them.

The various data was analysed in different modalities. Data from the logbook and the focus-group discussions and interviews were coded and categorised broadly in a grounded theory mode (Strauss & Corbin, 1998; Henning, Van Rensburg & Smith, 2004) without aiming to theorise directly from it, but just using the inductive ‘open’ and ‘axial’ coding mechanism of this analytical method. The content of lessons and the artefacts, including their use, were coded according to requirements/criteria for pedagogical content knowledge and tool-use in foundation phase mathematics teaching. In both these analyses, the process was, invariably, influenced by the ideas of Thomas and Brown (2009), much as ‘open coding’ was aimed for. Integration of thinking, making and playing, as described in the Thomas and Brown (2009) model of design and creation, was thus considered throughout the analysis. The video-recorded lessons were analysed per episodic unit for the use of the learning tools. The framing of the study is set out in Figure 2.
FINDINGS AND CONCLUSIONS

With the assistance of software we managed to create the open codes for the combined data, examples of which are presented in Figure 3. below, copied from three screenshots.
In the next level we then described the labelled codes – this time round we did it also manually. This is shown Figure 4.
Figure 4: Example of second level coding

To ensure that the process was reliable, we tested a few themes by making use of a flowchart in which we worked backwards to show one of the examples that traces, from the theme to the categories - and then to the codes.
After having traced themes that ran through the categories, the final themes and the overall pattern was established. Figure 6 shows how the different themes culminate in a pattern. We would like to claim that if student teachers were afforded the opportunity to view children’s learning, epistemologically, as part thinking, part making and part playing, that they may be able to view the tools they make as a conjoined effort with the learners in the classroom. It could well be that they fail to apply their tools conceptually, because they do not emphasise the intersect of childrens learning through making playfully.

In the paper we are not discussing the seven themes in any detail, but wish to point out that there is some coherence between each theme and the whole and that this strengthens the validity of the findings.

The strength of this study has been the lens of the triarchic framework, which assisted us in seeing the students’ learning and their mentoring from different vantage points. We could look at them as apprentices, as tool-makers and users and as pre-service teachers. The conclusion that we draw, is that the students are only at the beginning of their learning to be a tool-using teacher, that they are apprentices who work quite well in a supportive peer group, and that they are not yet able to use mediational artefacts for number concept learning.
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Gravett, S., Petersen, N. & Petker, G., 2014. Integrating foundation phase teacher education with a ‘teaching school’ at the University of Johannesburg. Education as Change, 18(sup1), S107-S119.


**ABSTRACT**

This study explores the use of Elaboration Framework as a tool for developing primary mathematics teacher’s Responses to answers and contributions of their pupils’ in the Nigerian Context. Four (4) teachers with strong content knowledge background were purposefully selected to for the study. Two lessons were each observed and qualitatively analysed using the framework. The results of this study indicate that in the context of relatively strong teachers in both content and pedagogy, the elaboration framework can be used in developing teachers’ responses to answers and contributions of their pupils in the classroom in the Nigerian context.

**INTRODUCTION**

The growing number of professional development (workshops) for primary school teachers in Nigeria on both teacher subject matter knowledge and pedagogical knowledge, indicates the need for supporting these teachers. Research evidence has shown that developing teachers’ knowledge for teaching does not directly translate into changing classroom practice (Abdulhamid, 2016; Rowland, 2005). This suggests the need for follow-up support to teachers at their work place (i.e. the classroom). This paper therefore explores ways of supporting mathematics teachers in their classroom using an Elaboration Framework.

The elaboration framework is an empirically based analytical tool for classifying situations that describe the range of teachers’ responses (and non-responses) to pupils’ answers and contribution during classroom interactions in a resource constrained context. Resource constraint context refers to the context with prevalent gaps in teachers’ content knowledge, pedagogy in the classroom, and lack of evaluation of pupils’ answers and contributions (Abdulhamid, 2016). The elaboration framework consists of three situations that elaborations are likely to occur. These are: (i) breakdown situations - where incorrect answers are given by pupils’; (ii) sophistication situations - where a correct answer is given, but is viewed by the teacher as inefficient in relation to either the representation or the strategy used by pupils’ in producing the answer; and (iii) individuation situations - of pedagogic moves of correct and efficient pupils’ answers and/or insight from chorused answer to assessing individuals (individuation) (iv) collectivisation situations - of pedagogic moves of...
correct and efficient pupils’ answers and/or insight from individual insights developed and projected to the collective classroom space (collectivization).

In each situation of elaborations two kind of broad categories of responses are possible: (i) Elaboration not Provided (ENP), where teacher ignores pupils’ answers and (ii) Elaboration Provided (EP), where the teacher acknowledges and incorporates pupils’ answers into the flow of the classroom interaction. In the context of relatively strong teachers and interim professional development involving Video Stimulated Recall interview (VSR), the elaboration framework provides three markers of development (Abdulhamid, 2016) these developments include: (i) Extent - this development focused on the number of incidents where elaboration was provided to the incidents where elaboration was not provided. (ii) Breadth – this development focused on scrutiny of the scope of the elaboration sub-types within situations and is considered in event where no hierarchy exists between the elaboration provided categories. (iii) Quality – this development focused on the scrutiny of the elaborations offered within the hierarchies of sub- types categories of each situation. This paper focuses on the last marker of development which is the development in quality of elaborations. Abdulhamid and Venkat (2017) see elaboration as a means of examining responsive teaching and also a vehicle for developing responsive teaching in the context of Video Stimulated Recall interview VSR.

VSR interview is central to the development of elaborations as a professional development mechanism. The VSR interviews as described within the elaboration framework incorporate opportunities for teachers to view and review video recordings of their own teaching in order to reflect on their practice. This enables the teachers to build increasing awareness of the unexpected events in the course of classroom interaction. This approach was found to be effective in getting insight into teachers’ thoughts and reflections on their own practice (Muir & Beswick, 2007), and has been used as an effective medium for promoting teacher professional learning in mathematics classrooms (Geiger, Muir, & Lamb, 2015).

LITERATURE REVIEW

For the teaching of mathematics to be effective, it has to be allowed to go with the emerging situation in the classroom. In other words, it has to be improvised and not based on scripted material because an effective mathematical teaching aimed at provoking reasoning and nursing meaningful ideas. This is because mathematics lessons hardly proceed according to plan (Foster 2014). The classroom interactions are unpredictable as it emerges from the activities of both the teacher and the pupils, and the actions of the pupils cannot be scripted, documented or predicted. Sawyer, 2004 conceived teaching as improvisational and highlights the collaborative and emergent nature of the effective practices which help us to understand the dynamics of classroom interactions and how a teacher support mathematics learning. (Ericson, 1982) also noted that “talk among teachers and students in the classroom can be seen as collaborative improvisation of meaning and social organization from
moment to moment” (p. 152). Since teaching is improvisational then it is conceived as creative with teachers ready to be responsive to classroom situations as teaching is taking place.

Responding qualitatively is a product of creativity of a teacher, which includes his or her ability to respond to challenging situations in the classroom swiftly in front of the learners (Lampert, 2001). Mason and Spence, (1999) described it as “knowing to act in the moment” or the ability to think on once feet as a reflective practitioner (Schon 1987). Rowland, Thwaites and Jared (2015) argued that the unpredictable nature of classrooms stem from at least three triggers which they call ‘contingency’ events and they are as follows:

- Arising from pupils’ ideas during the teaching or learning situation;
- Emanating from teacher’s insight through reflection of his or her own planned actions;
- Emanating from the pedagogical or specialized tools and resources that are brought to bear on the instructions, when the teacher is responding to the availability (or the unavailability of resources.

This paper focuses on the first trigger which is pupils’ ideas and answers because of the importance of acknowledgement and evaluation of the learners’ answers. The following responses are set out by Rowland et-al., 2015, as classes of responses to such triggers: (i) to ignore (ii) to acknowledge and put aside and (iii) to acknowledge and incorporate.

Abdulhamid and Venkat (2017) in addition, contributed to responding to pupils offer within the elaboration framework. They see elaboration as a means of examining teachers’ responses and it is also a vehicle for developing these responses. These elaborations argued by Abdulhamid and Venkat, formed the vehicle for developing teachers’ responses in the context of VSR to bring awareness to teachers practice in the classroom. This supports the teachers in the development of important stages towards more responsive teaching (teaching that acknowledges, evaluates and incorporate learners’ answers).

CONCEPTUAL FRAMEWORK

This paper is guided by an elaboration framework which is both the conceptual and analytical framework. It was developed as a model for lesson observation and developing important stages towards more quality response to pupil’s answers and contribution in the mathematics classroom. The elaboration framework is an empirically based analytical tool that categorizes teacher responses and non-responses to pupils’ answers and contribution in the mathematics classroom in a resource constrained context (Abdulhamid, 2016). By resource constrained refers to a context with prevalent gaps in teachers’ mathematics content knowledge and pedagogical knowledge in mathematics classroom. The framework presents three situations of elaborations as label in Table 1.

\[\text{Table 1: Categorization of Situational Nature of Elaborations}\]
### Situations of elaboration

<table>
<thead>
<tr>
<th>Situations of elaboration</th>
<th>Description</th>
<th>Goal of elaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakdown</td>
<td>Incorrect learner(s) offer</td>
<td>Eliciting correct mathematical offer</td>
</tr>
<tr>
<td>Sophistication</td>
<td>Correct learner(s) offer but viewed by the teacher as inefficient</td>
<td>Moving to more efficient mathematical strategy or representation</td>
</tr>
<tr>
<td>Individuation/Collectivisation</td>
<td>Correct chorus offer that is individuated or correct offer from individual learner that is collectivised by the teacher</td>
<td>Pedagogic move of chorus offer to assessing individual learners’ understanding or projecting individual learner’s mathematical offer to collective classroom space with some ‘unpacking’</td>
</tr>
</tbody>
</table>

### Breakdown Situation

This refers to the situations where incorrect pupils’ answers are given. Literature suggests that incorrect answers are inevitable and are intrinsic parts of mathematics learning situations (Foster, 2014). While many teachers viewed incorrect answers as a distraction to their class, there is also a wide agreement in the literature that incorrect answers if properly handled can provide a good background for knowledge construction in mathematics teaching (Askew & William, 1995; Vosniadou & Verschaffel, 2004). The breakdown situation of the elaboration framework, provide a comprehensive methodology on how a teacher can handled or response to incorrect answers in the mathematics classroom. This situation is divided into two broad categories of either Elaboration Provided (EP) or Elaboration not Provided (ENP), which were further divided into sub-types categories. Figure 1, describes the two broad categories of breakdown situation and their corresponding sub-types categories.

![Figure 7: Teacher’s Handling of Breakdown Situation of Elaboration (Abdulhamid & Venkat, 2017 p.10)](image)

In the sub-types categories under the elaboration provided, there are elaborations which focused on learner’s incorrect answers label as: (i) Restate learners’ offer and question its correctness and (ii) Probes the learners offer with follow-up question. The second is elaboration that focuses on task label as: (i) Verbal reframing using alternative phrase, (ii) Lead into the task, (iii) Switching between
representation, (iv) Establishing generality and (v) Contrasting offer and required operation. The elaborations that focused on learner’s incorrect offer are hierarchical, which provide the basis for developing quality of elaboration in term of response to incorrect answer (Abdulhamid, 2016). The elaborations that focused on task are not hierarchical but, they offer multiplicity of responses, which are basis for exploring breadth of elaboration within breakdown responses. There are four sub-types categories for elaboration not provided, thus: (i) Reduces cognitive demand of the task (ii) Repeats learners offer and moves on (iii) Repeats task and move on (iv) No comment and move on.

**Sophistication Situations**

This refers to the situations where a correct answer is given, but is viewed by the teacher as inefficient in relation to either the representation or the strategy used by students in producing the answer. Responding to learner’s inefficient strategies or representations is a necessary step for the support of understanding of connectedness of mathematical ideas (Ensor et al., 2009). This situation is divided into two broad categories of either EP or ENP, which were further divided into sub-types categories. Figure 2, describes the two broad categories of sophistication situation and their corresponding sub-types categories.

![Figure 8: Teacher’s Responses to Sophistication Situation of Elaboration (Abdulhamid & Venkat, 2017 P. 14)](image)

In the sub-types categories under the EP there are three (3) hierarchical incidences which provides a background for the understanding of the development of responsive teaching. They are label as: (i) Offers a more efficient strategy (ii) Elicit a more efficient learners offer and (iii) Interrogates learners’ offer for efficiency. Under the ENP category, there two non-hierarchical incidences and they are label as: (i) Acknowledges correct offer as inefficient and move on and (ii) Pulls learners’ back to inefficient action. Note in the sophistication situation, there is no breadth of elaboration because all incidences in the elaboration provided are hierarchical.

**Individuation/Collectivisation Situations**
This is a pedagogic move of correct and efficient student(s) answers and/or insight from either chorused offer to assessing individuals (individuation) or individual insights developed and projected to the collective classroom space (collectivization). Teachers response moves which attend to individual learner, while projecting and developing their answers with the whole class has been described to be beneficial to broadening opportunities for learning mathematics in the classrooms (Brown & Wragg, 1993; Rowland, Turner, Thwaites, & Huckstep 2009). This situation was divided into two broad categories of either elaboration provided or elaboration not provided, which were further divided into sub-types categories. Figure 3, describes the two broad categories of individuation/collectivisation situation and their corresponding sub-types categories.

![Figure 9: Teacher’s Responses to Individuation/Collectivisation Situation of Elaboration (Abdulhamid & Venkat, 2017 P. 17)](image)

In the sub-types categories under the EP there are there two (2) hierarchical incidences under individuating response and they are label as: (i) *Confirm chorus offer with individual learners* and (ii) *Interrogates chorus offer with individual learners*. There are also two (2) hierarchical incidences under collectivising response and they are label as: (i) *Confirm individual learner`s offer with whole class* and (ii) *Interrogates individual learner`s offer to the whole class*. There are also three (3) non-hierarchical incidences under the collectivising response of the EP category they are label as: (i) *Repeats individual learner`s offer with the whole class* (ii) *Decompresses individual learner`s offer to the whole class* and (iii) *Collective reasoning*. Under the ENP category, there are two (2) incidences and they are label as: (i) *Accept chorus offer and moves on* and (ii) *Accept individual offer and moves on*.

Table 2 presents the elaboration framework, with highlighting of the hierarchies within each dimension. The highlighted areas in the framework show the nine categories in which hierarchies exist. These include: the first two categories of breakdown elaborations; the three categories of sophistication elaborations; and four categories of individuation/collectivisation elaborations.
Table 2: The Elaboration Framework (Abdulhamid, 2016 P. 165)

<table>
<thead>
<tr>
<th>Situations of elaboration</th>
<th>Categories of response</th>
<th>Sub-types categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakdown Incorrect learner(s) offer</td>
<td>Elaboration Provided</td>
<td>Learner incorrect offer-focused responses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L1: Restates learners’ offer and questions its correctness</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L2: Probes the learner’s offer with follow-up question</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Task-focused responses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Verbal reframing using alternative phrase</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lead-in to the task</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Switching between representations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Establishing generality</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contrasting offered and required operation</td>
</tr>
<tr>
<td></td>
<td>Elaboration Not Provided</td>
<td>Reduces cognitive demand of the task</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repeats learner’s offer and moved on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repeats task and moved on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No comment and moved on</td>
</tr>
<tr>
<td>Sophistication Correct learner(s) offer but viewed by the teacher as inefficient</td>
<td>Elaboration Provided</td>
<td>L1: Offers a more efficient strategy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L2: Elicits a more efficient learner’s offer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L3: Interrogates learner’s offer for efficiency</td>
</tr>
<tr>
<td></td>
<td>Elaboration Not Provided</td>
<td>Acknowledges correct offer as inefficient and moves on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pulls learners’ back to inefficient action</td>
</tr>
<tr>
<td>Individuation/Collectivisation Correct chorus offer that is individuated or correct offer from individual learner that is collectivised by the teacher</td>
<td>Elaboration Provided</td>
<td>Individuating responses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L1: Confirms chorus offer with individual learners</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L2: Interrogates chorus offer with individual learners</td>
</tr>
<tr>
<td></td>
<td>Collectivising response</td>
<td>L1: Confirms individual learner’s offer with whole class</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L2: Interrogates individual learner’s offer to the whole class</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repeats individual learner’s offer with the whole class</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decompresses individual learner’s offer to the whole class</td>
</tr>
<tr>
<td></td>
<td>Collective reasoning</td>
<td>Accepts chorus offer and moved on</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Accepts individual offer and moved on</td>
</tr>
</tbody>
</table>

Indicators of Development in Elaboration

As earlier pointed out in the introduction chapter, the elaboration framework in the context of relatively strong teachers and interim professional development involving VSR provides three markers of development. These developments include: (i) Developments in term of extent, (ii) Developments in term of breadth and (iii) development in term of quality. These developments were based on the counts of incidence where elaboration was seen in the two cycles of lesson observations. Each incidences of elaboration that were observed, the teacher’s utterances/responses
were coded. However, wherever a particular utterance, which had already been coded, was repeated within the same incident, the repeat utterance was not counted. This will form the basis for the count of the EP and ENP incidences for each teacher’s lessons enactment. This paper will focus on the last development which is development in quality of elaboration.

Quality of Elaboration
Development in term of quality focused on scrutiny of the elaborations offered within the hierarchies of sub-types categories of each situation. For example, within the breakdown situation, more incidents of probing a learner’s offer rather than restating a learner’s offer and questioning its correctness indicate a marker of ‘quality’ of elaboration (Abdulhamid, 2016). In the sophistication and individuation/collectivization situations, more incidence of higher level than the lower level response in the sub-type’s categories indicate a development in terms of quality of elaborations.

METHODOLOGY

In this paper, I report on a qualitative case study where four (4) primary mathematics teachers with pseudo names Aisha, Lawan, Amina and Maimuna were purposefully selected, to exemplify the nature of the quality of elaboration in their mathematics teaching. Three out of the four teachers are generic teachers teaching all subjects in primary three including mathematics while the fourth teacher is also a generic teacher teaching all subjects including mathematics in primary two. I observed two cycles of their lessons with interim video stimulated recall (VSR) interview. The lessons were coded using the elaboration framework. The purpose of the VSR interviews was to gain insight into teachers’ thoughts on classroom decisions, and to support the development of their quality of responses to the answers and contributions to their pupils’ offers. A teacher’s quality of responses to pupils’ offerings can be observed in all the three situations of elaborations as pointed out by the elaboration framework.

RESULTS

Table 3 shows the results of coding of the four teachers on how they handled responds to their learners offer in the two cycles of lessons. The results show some progress in providing quality elaborations in some of the situations of elaborations as highlighted by the Elaboration framework. Key responses are exemplified with excerpts illustrating how the teachers responds to some of the answers and contribution of the learner’s offerings. Provide Elaboration as related to learner offers: probes learner’s offer; related to task: verbal reframing and other sub types categories indicating quality of elaborations.
Excerpt 1: Amina (Restates learners offer and question its correctness Breakdown)

In the context of the task 42 + 26 using column form to solve, Individual learner offered ‘six’ as answer to 2 + 4

T: two plus four she pointed to a learner
L: Five
T: Five? I mean two plus four, will it give us five?

Excerpt 2: Aisha (Interrogating chorus offer with individual learner individuation)

In the context of adding numbers and identifying the addend as either even or odd, teacher asked whether ‘four’ is an even number or odd number.

T: Is four even or odd?
C: even number (in chorus)
T: Why is it an even number? Did you count it? (Pointing to individual learner)

Excerpt 3: Lawan (Interrogates individual learner’s offer with the whole class Collectivisation)

T: two minus one? (He points to a learner) L: Two
T: Is he correct class? Can you tell me how?

CONCLUSION

It is observed that, there is a development in quality elaborations in the two out of the three situations of elaborations. No development in terms of quality elaborations were observed in the one of the situations of elaborations. This may be attributed to the low-level cognitive demand of the tasks. In developing quality of elaborations, Rowland, et-al 2015 suggested that teachers with strong content Knowledge background are necessary but not sufficient for responding qualitatively to answers and contribution to learners’ offers. As such emphases should be given to the content background of the teachers to be observed.
REFERENCES


MATHEMATICAL KNOWLEDGE FOR TEACHING IN MALAWI: How Do Primary Preservice Teachers Perceive It?
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ABSTRACT
This article discusses how primary preservice teachers in Malawi perceive the mathematical knowledge for teaching. Drawing on the practice-based theory of mathematical knowledge for teaching, the study analyzed the preservice teachers’ views about the elements that compose the domains of common content knowledge, horizon content knowledge, and specialized content knowledge. The data was collected from interviews with six primary preservice teachers at the beginning of their teacher training college, and the findings revealed that primary preservice teachers in Malawi construct different discourses about the knowledge and skills needed to teach mathematics in primary schools. These results provide insights into the development of new strategies in teacher training programs and a better understanding of what characterizes mathematical knowledge for teaching in Malawi.

Keywords: primary teacher education; mathematical knowledge for teaching; Malawian teacher education.

INTRODUCTION
A recent study conducted at all of the eight teacher colleges in Malawi concluded that there is a statistically significant increase in the preservice teachers’ mathematical knowledge for teaching during their training (Jakobsen, Kazima, & Kasoka, 2018). However, the change in mathematical knowledge for teaching is relatively small, and most preservice teachers’ mathematical knowledge for teaching improved little during teacher training at their teacher-training college (TTC). In addition, most preservice teachers begin college with a feeble understanding of basic mathematics, and essential knowledge and skills for teaching mathematics did not improve because of the training programs (Kasoka, Jakobsen, & Kazima, 2017). While previous studies have looked at the change in mathematical knowledge for teaching during TTC, there is a need to understand more about what beginner teachers do in their teacher-training programs in Malawi, how they understand and evaluate their own lessons, and on what bases they choose to act in particular ways instead of others. This paper, therefore, presents the first results of a larger research that examines the primary preservice teachers’ making sense process of mathematical knowledge for teaching in Malawi. The
question addressed is: what are the Malawian primary preservice teachers’ perceptions of mathematical knowledge for teaching at the beginning of teacher education?

Teacher’s mathematical knowledge for teaching

During the last decade, there has been a significant increase in international research focusing on teachers’ knowledge (Nóvoa, 2004). In the field of mathematics education, one of the promising trends is the work of Deborah Ball and her colleagues at the University of Michigan in the USA. Their theory about mathematical knowledge for teaching based on ideas that endure what is crucial for effective mathematics instruction (Ball, Thames, & Phelps, 2008). The theory encompasses six domains: common content knowledge (CCK), horizon content knowledge (HCK), specialized content knowledge (SCK), knowledge of content and students (KCS), knowledge of content and teaching (KCT), and knowledge of content and curriculum (KCC). In this paper, the focus will be on the domains of CCK, HCK, and SCK.

CCK refers to the mathematical knowledge commonly used or produced in a variety of settings, also outside teaching. This type of knowledge “is not specialized understandings but questions that typically would be answerable by others who know mathematics” (Ball et al., 2008, p. 399). Using an algorithm to find the answer for a subtraction problem is an example of CCK. HCK, on the other hand, is the knowledge of “how the content being taught is situated in and connected to the broader disciplinary territory” (Jakobsen, Thames, Ribeiro, & Delaney, 2012, p. 4642). This category involves the understanding of the subject’s origins and principles as well as how valuable it can be to the student’s learning. As a contribution, HCK enables teachers “to make judgments about the importance of particular ideas or questions” of students and address “the discipline with integrity, all resources for balancing the fundamental task of connecting learners to a vast and highly developed field” (Jakobsen et al., 2012, p. 4642).

<table>
<thead>
<tr>
<th>Presenting mathematical ideas</th>
<th>Responding to students’ “why” questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finding an example to make a specific mathematical point</td>
<td>Recognizing what is involved in using a particular representation</td>
</tr>
<tr>
<td>Linking representations to underlying ideas and other representations</td>
<td>Connecting a topic being taught to topics from prior or future years</td>
</tr>
<tr>
<td>Explaining mathematical goals and purposes to parents</td>
<td>Appraising and adapting the mathematical content of textbooks</td>
</tr>
<tr>
<td>Modifying tasks to be either easier or harder</td>
<td>Evaluating the plausibility of students’ claims (often quickly)</td>
</tr>
<tr>
<td>Giving or evaluating mathematical explanations</td>
<td>Choosing and developing useable definitions</td>
</tr>
<tr>
<td>Using mathematical notation and language and critiquing its use</td>
<td>Asking productive mathematical questions</td>
</tr>
<tr>
<td>Selecting representations for particular purposes</td>
<td>Inspecting equivalencies</td>
</tr>
</tbody>
</table>

*Figure 1. Mathematical Teaching Tasks (Ball et al., 2008)*
The domain of SCK is “the mathematical knowledge unique to the work of teaching” (Ball et al., 2008, p. 400). It “involves an uncanny kind of unpacking of mathematics that is not needed—or even desirable—in settings other than teaching” (Ball et al., 2008, p. 400). It includes the capacity for identifying and explaining ideas during instructional tasks, making sense of effective teaching methods, and anticipating students’ ideas. SCK is a special type of knowledge that is mainly needed to perform teaching tasks (Figure 1).

The theory of mathematical knowledge for teaching has proven to have positive effects on student performance (Hill, Howan, & Ball, 2005). It provides useful concepts that act as an analytical lens to examine the teaching activity from a conceptual perspective (Johnson, 2009). In this study, the theory of mathematical knowledge for teaching is used as an analytical approach to enlighten the analysis of the cases and as a tool to guide the research actions in the fieldwork.

METHODOLOGY AND DATA ANALYSIS

The study presented in this paper was designed as a multiple case study (Stake, 2006). Multiple case studies help explore the cases in their real forms and natural contexts by combining different instruments with the purpose of analyzing a case from different angles and producing relevant evidence to test theories (Platt, 2007). Thus, the primary sources for a multiple case study are cases that can provide preeminent understandings of the diversity within the universe investigated.

The universe in focus is the teaching-learning process of Malawian primary preservice teachers, in particular, their perceptions of mathematical knowledge for teaching. The methodology was structured through two instruments: a questionnaire and semi-structured interviews. The questionnaire was applied in two classes of primary preservice teachers from a two-year teacher-training program in a Malawian teacher training college. Twenty-three preservice teachers volunteered to participate in the study. In general, the questionnaire covered questions about participants’ professional interests, educational conceptions, and experiences in mathematics teaching, and the interviews questions regarding the knowledge and skills that a primary teacher needs to know to teach mathematics effectively (Ball et al., 2008).

This paper presents data from six preservice teachers over three analysis categories that emerged from the domain of CCK, HCK, and KCS. The first category, Perceptions of mathematical knowledge within (CCK) and outside the curriculum (HCK), examined the participants’ views about the importance of mathematical contents within and outside the primary school curriculum. The second category, Knowledge of learners’ errors as a strategic pillar for SCK, assessed the preservice teachers’ perceptions of student’ mistakes. The focus was on their views and arguments on what is relevant for a teacher to know about children’s errors and how teachers should interpret them. The third category, Learning engagement through approach diversification, captured the preservice teachers’ perceptions of different ways of teaching mathematics in primary schools in Malawi. The focus is to
understand how the preservice teachers perceive the methodological work of teaching and how it can affect the children’ mathematics learning.

With these three categories in mind, the aim was to obtain evidence for a better understanding of what preservice teachers in Malawi perceive as mathematical knowledge for teaching. Moreover, those analyses will give new insights for a better understanding of the domains of CCK, HCK, and SCK from the Malawian primary preservice teachers’ views at the beginning of their teacher training college.

FINDINGS AND DISCUSSION

Perceptions of mathematical knowledge within (CCK) and outside curriculum (HCK)

To become a primary school teacher in Malawi, candidates need to acquire appropriate pedagogical knowledge in the teaching and learning of topics that enable primary school learners to acquire, interpret, and apply them in everyday life. Some of the main topics in the Malawian mathematical curriculum are pedagogical knowledge of numbers, operations, and measurements (Malawi Institute of Education, 2017). In this category, preservice teachers expressed their ideas about the importance of curricular mathematical content and how useful it is for a teacher. Some comments representing this category are as follows:

Pst J:  *I think it is very important for the teacher to know the content of the curriculum because he can teach what is important for the learners.*

Pst A:  *He must know the content he needs to teach; otherwise, he will confuse the students.*

Pst C:  *If the teacher knows the content, he will have more confidence in the classroom, and the learners will know that he is wiser.*

The comments above shows the preservice teachers acknowledged that the curriculum enhances the effectiveness of both teaching and learning. When possessing in-depth knowledge of curricular mathematical concepts, teachers are capable of teaching in several ways (Ball et al., 2008). Another preservice teacher, for example, explained that “teaching is about helping learners to learn from simple to complex, from known to unknown; and the curriculum tells us the simple concepts that they need to learn” (Pst G).

The preservice teachers’ perceptions of curricular mathematical content converged on its relevance but differed on the significance of the mathematical content outside the curriculum. Some claimed that it is not crucial for primary teachers once governmental authorities have provided guidance on what is to be taught.
PsT C: The ministry of education already applies what the learners have to know at the primary level, so if the teacher is out of the curriculum, he can teach things that are not intended for primary learners.

PsT A: Not so important for the teacher because it can confuse himself.

PsT J: If the teacher teaches a content which is not in the curriculum, he will confuse the students.

PsT D: The learners will not use this content, so it is not important.

Others, however, demonstrated a balanced point of view illustrating positive and negative aspects of knowing and teaching mathematical concepts not included in the curriculum.

PsT D: It is not so important to know mathematics outside of the curriculum, but the teacher needs to know it to make easier for the learners.

PsT H: Of course you should know more mathematics, but only when you move to the secondary level.

PsT E and F, however, differed with their colleagues.

PsT E: It is very important because they can reflect on what they are teaching.

PsT F: Yes, it is important because, with another content, you can explain better, you can mix it, and add new ideas.

These two preservice teachers perceived knowledge of the mathematical contents not contained in the curriculum as an important characteristic of an effective primary teacher in Malawi. To acquire a better understanding of the content and forms of teaching, they believed teachers need to reflect, experiment, and try out new ideas. Bringing complex concepts and new problems from real-life situations into the classroom “may not be easy for the teacher, but it can challenge and stirs creativity among the learners” (PsT E).

Kelly (1999) observed that, in some contexts, curriculum contents might “limit the planning of teachers to a consideration of the content or the body of knowledge they wish to transmit or a list of the subjects to be taught or both” (p. 83). Knowledge of the content that lies outside the curriculum they teach is also important to the work of teaching. In the classroom, teachers should provide learning environments that make the students experience real situations that encompass multiple concepts.

In general, the analysis also revealed differences among the preservice teachers’ perceptions. Most primary preservice teachers consented to the importance of knowing the curricular mathematical content, but few supported the need for expanding this knowledge outside the curriculum. Therefore
most preservice teachers substantiated their perceptions of CCK and HCK on what is available of classroom resources and what is relevant for children to learn in primary schools.

**Knowledge of learners’ errors as a strategic pillar for SCK**

Although mastering the mathematical knowledge within and outside the curriculum is an essential component of teaching, the pedagogical content knowledge is the one that shapes students’ learning experiences (Ball et al., 2008). Any teacher, who knows their students and prior knowledge, is capable of identifying, explaining, and even predicting what pupils can do or not do during learning activities (Freire, 1999). Understanding learners’ mistakes and help them be aware of ways to fix it is the focus of this category. Three sub-themes will be considered: a) interpreting pupils’ ideas; b) anticipating student’s mathematical responses; c) explaining where and how learners’ mistakes happen.

For the first theme, some of the preservice teachers spoke about the limits of knowing their students. Their comments were:

*PsT A:* Teachers should know what the learners are capable of doing, but in Malawi, it is very difficult! We have so many children in the classroom that you cannot know everyone. [...] I used to teach in four classes, each with more than one hundred.

*PsT E:* Learners can come across with a different challenge or problem in their lives, so the teacher needs to be familiar with it, or the learners will not be involved in the lesson.

*PsT F:* We need to give them a chance to interact with what we are teaching. Thus, they can help us to create different lessons and improve our curriculum.

Other preservice teachers’ responses focused on the teachers’ role in students’ mistakes.

*PsT G:* You are there to teach, so you are there to check the mistakes. You should correct them so they can have the correct information.

*PsT A:* If learners find difficult one thing, they will not understand the whole lesson; teachers need to find extra time to help them.

*PsT F:* You can help them by giving another view, so they can understand mathematics and solve the problems.

*PsT E:* The teacher has to ask them, how did you come up with this answer? How did you solve it? So the teacher can know where the problem comes from. Just giving them the answer, they cannot understand where they are wrong.

The arguments above illustrate a vital characteristic of primary school teachers: they should not only identify children’s inaccuracies and errors but also help them to find out what led them to make them. The Malawian preservice teachers’ perceptions of the need for understanding the students’
mistakes and their characteristics reflected their efforts in recognizing different ways to help them to fix them. Knowing to interact with students is an important characteristic of primary school teachers (Ball et al., 2008) so that the learners can have the opportunity to express their thoughts and ideas, and reflect on what is being learned. Children’s learning should not occur apart from the context and in isolation from the others, it should be supported by someone more familiar with the topic, someone with prior knowledge of the subjects and capable of understanding and making them understandable. Thus, from the preservice teachers’ views, teachers play a significant role in the children learning by making them aware of the mistakes and new ways of solving a problem.

**Stimulating learning through different approaches**

In this third category, the main focus is the way how the Malawian preservice teachers perceive different forms of teaching mathematics instead the textbook suggests. This element is one significant characteristic of SCK—a type of knowledge that allows teachers to engage children in particular tasks. Such tasks might include “representations of mathematical ideas, mathematical explanations for common rules and procedures, or exploring unusual solution methods to solve a problem” (Hill et al., 2005, p. 378). Thus, in this category, the preservice teachers expressed their views about the knowledge and skills to teach a mathematical concept is multiple ways. The most significant comments were:

*PsT D:* *When learners have a different situation in their life, they are facing a new challenge that requires new ways to solve it. So teachers can use these challenges to teach mathematics.*

*PsT L:* *In Malawi, we have Kwacha. So you can relate it in the classroom. How much does it cost to go to Blantyre? You have to negotiate and think, you know.... Is it expensive? So this can be a way to engage learners.*

*PsT A:* *One example is the abacus. It can be a very powerful resource to help the learners to see what we are teaching.*

Although they illustrated different forms of thinking in the previous categories, most preservice teachers described teaching approaches for teaching Mathematics regarding two similar concepts: creating problematic situations and using manipulative materials. Moura (2010) describes problematic situations as a contextualized problem from which teachers can explore students’ curiosity by engaging them in problematic real-life situations. This type of approach is intentionally organized to developed students’ curiosity and critical thinking. PsT L’s comments reflected such an idea when he emphasized a common situation in Malawi: transportation costs. He argued [*... to go to school, they have to take the minibus every day, so they can apply what they learn in class. By knowing how to engage students in stimulating activities that challenge them, teachers can help learners acquire historically and culturally constructed concepts that explicate their reality (Moura, 2010).*
In the other site, PsT A talked about the use of an abacus as a manipulative material for teaching mathematics. He noted the importance of this tool for children to gain a deep understanding of mathematics concepts. Miller and Stigler (1991) emphasize that manipulative materials increase children’s ability to perform mental calculations and representations, and teaching mathematics through manipulative materials improve the environment in the math classroom (Smith, Babione, & Vick, 1999). Thus, the practical use of manipulative materials helps teachers to spark students’ imagination by letting them touch, move about, rearrange, and otherwise handle objects (Kennedy, 1986, p. 9).

CONCLUSIONS

Considering that teaching mathematics demands a distinctive brand of knowledge and skills unique to the work of teaching (Ball et al., 2008), this paper examined the Malawian primary preservice teachers’ perceptions of mathematical knowledge for teaching, in particular, conceptual aspects the characterize the domains of CCK, HCK, and SCK. The results indicated that primary preservice teachers in Malawi construct different forms of interpretation of mathematical knowledge for teaching and use solid arguments that corroborates with the theory suggested by Ball et al. (2008).

By questioning the importance of the main elements that determine an effective mathematics teaching in primary schools in Malawi, we observed that, from the preservice teachers’ views, knowledge of curricular mathematical content shapes and supports what is essential for learners to know, and the mathematical knowledge outside curriculum helps teachers to make connections with real-life situations. We also identified a consent among primary preservice teachers that knowing a range of methods increases the opportunities to improve the quality of learning by engaging learners. These results provide insights for further research on whether preservice teachers’ perceptions of what is useful for the work of teaching correspond with what they will do in teaching practice. Those findings benefit the development of new strategies in teacher training programs and contribute to a better understanding of the main concepts of the practice-based theory of mathematical knowledge for teaching.

BIBLIOGRAPHICAL REFERENCES


MALAWI MATHEMATICS TEACHER EDUCATORS BELIEFS ABOUT MATHEMATICS, LEARNING AND TEACHING

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Abstract

In this paper we investigate Malawian mathematics teacher educators’ beliefs about mathematics, learning and teaching mathematics. Their beliefs are measured using an instrument developed by Beswick (2005) consisting of 26 Likert scale items. The questionnaires were distributed to all mathematics teacher educators at the eight teacher training colleges in Malawi and 44 answered. A descriptive presentation of their answer is given and compared to Australian teachers’ beliefs. The result shows a stronger focus on beliefs about mathematics teaching focusing on content and performance, and beliefs about mathematics learning shift more towards skill mastery and passive reception of knowledge compared to the Australian teachers.

Introduction

Teacher educators (hereafter TEs) rank on the top of the educational hierarchy. They play an important role for prospective teachers’ learning, and hence, they shape the future teachers and play an important role for the quality of student’s learning. Researchers have for centuries addressed different aspects that concern the quality of mathematics teachers, such as knowledge, practices and identity (Ponte, 2011). Identity can be seen as the embodiment of different aspects like beliefs, knowledge and affect, hence, research on teacher beliefs those address an important aspect of teacher identity (Ponte, 2011).

TEs’ beliefs are equally important for two reasons: i) the close connection between TE’s and (prospective) teachers’ beliefs within cultural contexts (Wang & Hsieh, 2014), and ii) the fact that the work of teaching in schools shares much in common with the work of the TEs. Wang and Hsieh (2014) found that in the same country (prospective) teachers’ beliefs and TEs’ beliefs are homogeneous. This suggests that a countries teacher education and its TEs are important factors for shaping teachers beliefs. In this short paper, we report on the following research questions: i) What are the Malawian TEs’ beliefs about mathematics, learning of mathematics, and mathematics teaching, and ii) What characterize the Malawi TEs’ beliefs compared to findings from Beswick (2005) in Australia, measured using the same instrument.
Literature review

Philipp (2007) presented some of the concepts that have been used when affective perspectives have been investigated in mathematics education research: affect (including emotions, attitudes and beliefs), beliefs systems, conceptions, identity, knowledge and values.

Beswick (2005) has made some clarifications concerning mathematics teachers’ beliefs which have often been grouped into beliefs about the nature of mathematics, about mathematics teaching and about mathematics learning. She summarizes connections among categories of beliefs about the nature of mathematics, beliefs about mathematics learning and to mathematics teaching.

Method

A questionnaire with 26 Likert Scale items adapted from Beswick (2005) was distributed to Mathematics teacher educators’ at all eight teacher training colleges in Malawi. 44 TEs answered the questionnaire about their belief, and their answers were compared with answers from 25 Australian teachers’ beliefs reported as by Beswick (2005). In this paper, a descriptive presentation of the answers (in percent) within each group are given.

Results

This short paper only contains a preliminary analysis of the data. While most responses among Malawi TEs are similar to the response reported by Beswick (2005), a few items stand out with very different responses. For instance, while item 5 shows that the majority of both Malawi TEs (70%) and Australian teachers (88%) SA and A with the statement “Effective mathematics teachers enjoy learning and ‘doing’ mathematics themselves”, there are far more Malawian TEs that D or SD with this statement (18% as opposed to 4% in Australia). Also, while the majority both in Malawi and Australia SA and A with the statement “Allowing a child to struggle with a mathematical problem, even a little tension, can be necessary for learning to occur.” far more Malawi TEs D or SD with this statement (23% as opposed to 4%). In item 15, 100% of the Malawian TEs SA and A with the statement “Teachers can create, for all children, a non-threatening environment for learning mathematics”, while only 64% of the Australian teachers agreed with this, and 16% D or SD. This indicates an instrumentalist view of mathematics, mathematics teaching should be content focused and emphasizes performance (Beswick, 2005).

There are also more TEs in Malawi than teachers in Australia that share the belief that mathematics learning is passive reception of knowledge. This is revealed in item 24 with the statement: “Listening carefully to the teacher explain a mathematics lesson is the most effective way to learn mathematics”. 33% of the Malawian TEs SA or A with this statement, compared to only 4% of the Australian teachers.
Table 1. Malawi TEs responses (in percent) for each item. Numbers reported by Beswick (2005) are given parentheses. SA = Strongly Agree, A = Agree, D = Disagree, SD = Strongly Disagree.

<table>
<thead>
<tr>
<th>Item</th>
<th>SA &amp; A</th>
<th>Undecided</th>
<th>D &amp; SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. A vital task for the teacher is motivating children to solve their own mathematical problems.</td>
<td>95 (100)</td>
<td>0 (0)</td>
<td>5 (0)</td>
</tr>
<tr>
<td>2. Ignoring the mathematical ideas that children generate themselves can seriously limit their learning.</td>
<td>95 (96)</td>
<td>5 (4)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>3. It is important for children to begin to develop opportunities to reflect on and evaluate their own mathematical understanding.</td>
<td>90 (92)</td>
<td>5 (8)</td>
<td>5 (0)</td>
</tr>
<tr>
<td>4. It is important for teachers to understand the structured way in which mathematics concepts and skills relate to each other.</td>
<td>98 (92)</td>
<td>0 (4)</td>
<td>2 (4)</td>
</tr>
<tr>
<td>5. Effective mathematics teachers enjoy learning and ‘doing’ mathematics themselves.</td>
<td>70 (88)</td>
<td>12 (8)</td>
<td>18 (4)</td>
</tr>
<tr>
<td>6. Knowing how to solve a mathematics problem is as important as getting the correct solution.</td>
<td>86 (88)</td>
<td>9 (4)</td>
<td>5 (8)</td>
</tr>
<tr>
<td>7. Teachers of mathematics should be fascinated with how children think and intrigued by alternative ideas.</td>
<td>95 (88)</td>
<td>5 (4)</td>
<td>0 (8)</td>
</tr>
<tr>
<td>8. Providing children with interesting problems to investigate in small groups is an effective way to teach mathematics.</td>
<td>90 (88)</td>
<td>0 (0)</td>
<td>5 (12)</td>
</tr>
<tr>
<td>9. Mathematics is a beautiful, creative and useful human endeavour that is both a way of knowing and a way of thinking.</td>
<td>93 (76)</td>
<td>2 (12)</td>
<td>5 (12)</td>
</tr>
<tr>
<td>10. Allowing a child to struggle with a mathematical problem, even a little tension, can be necessary for learning to occur.</td>
<td>58 (72)</td>
<td>19 (24)</td>
<td>23 (4)</td>
</tr>
<tr>
<td>11. Children always benefit by discussing their solutions to mathematical problems with each other.</td>
<td>88 (72)</td>
<td>5 (20)</td>
<td>7 (8)</td>
</tr>
<tr>
<td>12. Persistent questioning has a significant effect on children’s mathematical learning.</td>
<td>75 (68)</td>
<td>16 (28)</td>
<td>9 (4)</td>
</tr>
<tr>
<td>13. Justifying the mathematical statements that a person makes is an extremely important part of mathematics.</td>
<td>79 (64)</td>
<td>19 (24)</td>
<td>2 (12)</td>
</tr>
<tr>
<td>14. As a result of my experience in mathematics classes, I have developed an attitude of inquiry.</td>
<td>86 (64)</td>
<td>9 (24)</td>
<td>5 (12)</td>
</tr>
<tr>
<td>15. Teachers can create, for all children, a non-threatening environment for learning mathematics.</td>
<td>100 (64)</td>
<td>0 (20)</td>
<td>0 (16)</td>
</tr>
<tr>
<td>16. It is the teacher’s responsibility to provide children with clear and concise solution methods for mathematical problems.</td>
<td>60 (60)</td>
<td>21 (12)</td>
<td>19 (28)</td>
</tr>
<tr>
<td>17. There is an established amount of mathematical content that should be covered at each grade level.</td>
<td>86 (56)</td>
<td>5 (28)</td>
<td>9 (16)</td>
</tr>
</tbody>
</table>

*5 percent of the Malawi TEs had not provided any answer to this question*
18. It is important that mathematics content be presented to children in the correct sequence. 96 (48) 2 (32) 2 (20)

19. Mathematical material is best presented in an expository style: demonstrating, explaining and describing concepts and skills. 65 (32) 12 (40) 18 (28)

20. Mathematics is computation. 53 (20) 26 (20) 21 (60)

21. Telling the children the answer is an efficient way of facilitating their mathematics learning. 9 (16) 7 (12) 84 (72)

22. I would feel uncomfortable if a child suggested a solution to a mathematical problem that I hadn’t thought of previously. 5 (12) 5 (4) 90 (84)

23. It is not necessary for teachers to understand the source of children’s errors; follow-up instruction will correct their difficulties. 16 (8) 5 (8) 79 (84)

24. Listening carefully to the teacher explain a mathematics lesson is the most effective way to learn mathematics. 33 (4) 16 (36) 51 (60)

25. It is important to cover all the topics in the mathematics curriculum in the textbook sequence. 54 (4) 23 (4) 23 (92)

26. If a child’s explanation of a mathematical solution doesn’t make sense to the teacher it is best to ignore it. 7 (0) 2 (0) 91 (100)

References


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7 5 percent of the Malawi TE had not provided any answer to this question
STUDENT TEACHERS’ USE OF SHORT VIDIO CLIPS AS A VISUALISATION MEDIUM IN THE TEACHING OF MATHEMATICS
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Abstract
This paper reports on a recent study that was done in Zambia with a group of student teachers who utilised mobile phones as visualisation tools in the teaching of number sense. Visualisation is increasingly being recognised as having a significant role in the learning of mathematics, especially when students are solving mathematical problems (Thornton, 2001). This paper argues that visualisation is a powerful tool for learners to construct mental and physical representations that appropriately mirror mathematical relationships and concepts. To gain a thorough understanding of the scope of visualisation, three Visual Technology for Autonomous Learning of Mathematics (VITALmaths) (www.vitalmaths.com) video clips were uploaded on mobile phones of each of the eleven participating student teachers who used them in their teaching practice. This is in cognisance of the educational potential offered by mobile phones and their current pervasiveness in the daily lives of both teachers and learners in Zambia (Zambia. Ministry of Education [M.O.E], 2013]). This study sought to investigate how selected VITALmaths video clips on mobile phones could be used by student teachers as a visualisation tool in the teaching of number sense. The video recordings of the lessons formed the core of my analysis. The study was conducted at four primary schools by eleven student teachers of a public university in Zambia. The study was framed as a case study, grounded within the interpretive paradigm and the theoretical framework was constructivism.

The findings revealed that the student teachers’ use of the selected video clips in the classrooms for teaching Number Sense was generally approached from two perspectives: firstly, at the beginning of the lesson to introduce a topic, or at the end of the lesson to consolidate what was taught. The videos were also used to enhance the conceptual understanding of number sense. The findings also revealed that students encountered both enabling and constraining factors in their use of mobile phones to teach number sense. The overall findings revealed that, if appropriately utilised, mobile phones as visualisation tools had the potential to enhance the teaching of mathematics in general and number sense in particular, and therefore teachers should be encouraged to use them in their teaching.

Introduction
The past few decades have witnessed an increasing recognition of the role of technology in all educational domains across the globe. The digital and information revolution has changed the way learning and teaching takes place in many schools across the world Okello, (2010). It has however
also been argued by the Zambian Ministry of Education (2007) that many African countries, Zambia included, do not provide quality education to its learners because they do not take advantage of the potential Information and Communication Technology (ICT) offers to facilitate teaching and learning (Zambia. Ministry of Education [MOE], 2007).

The aim of the broader study within which this paper is located was to investigate how Visual Technology for the Autonomous Learning of Mathematics (VITALmaths) (www.vitalmath.com) video clips on mobile phones could be used as a visualisation tool by selected student teachers in the teaching of number sense. The study was conducted in selected primary schools in Zambia and took the form of a case study.

**Visualisation processes as a teaching tool/medium**

Thornton (2001) observes that there is a growing recognition that visualisation can play a significant role in the teaching and learning of mathematics, and the solving of mathematical problems. Arcavi (2003) contends that

“Visualisation is the ability, the process and the product of creation, interpretation, use of and reflection upon pictures, images, diagrams, in our minds on paper or with technological tools, with the purpose of depicting and communicating information, thinking about and developing previously unknown ideas and advancing understanding”, (p.217).

M.O.E. (2014) in Zambia specifically acknowledges that visualisation is a vital skill that is indispensable in the learning and application of mathematics and is also an important cognitive tool in problem solving. According to Guzm’an (2002) mathematical visualisation is an explicit process or act one engages in when representing an abstract mathematical concept in a more concrete manner in order to possibly facilitate a more efficient approach to solving a mathematical problem.

The role of visualization in mathematics teaching and learning is manifold and has been a subject of much research, (Arcavi, 2003; Bishop, 1989; Eisenberg & Dreyfus, 1986; English, 1997; Kadunz & Straesser, 2004; Presmeg, 1992; Stylianou & Silver, 2004). These visualisation roles include: facilitating understanding, enabling learners to simplify mathematical problems, making connections between mathematical concepts and the real world, transforming an abstract mathematical idea into a concrete construct (Ho, 2010). Guzm’an (2011) states that:

> Visualisation is therefore extraordinarily useful in the context of the initial processes of mathematics as well as in that of the teaching and learning of mathematics. All this makes very clear the convenience of training our own visual ability and introducing it to those to whom we are trying to introduce mathematics (p. 31).

This study thus sought to research how selected student teachers made use of a visualisation approach to teaching number sense through the medium of short video clips on mobile phones.
According to Makina (2010) visualisation, in particular dynamic visualisation is a very important feature in “teaching for understanding” in mathematics because it aids the teacher by engaging learners in realistic situations. The use of video clips in this study was an attempt to make visualisation of a mathematical idea or concept dynamic and real.

One of the strengths of visualisation lies in problem solving because of its potential to model different types of problems, its ability to engage learners in the processes of reason, and its engagement in higher-order thinking centred on problem solving, Kadunz & Straesser (2004). Furthermore, it is argued that visual narratives using animations such as video clips can provide effective tools to use visualisation in collaborative ways to engage with mathematical ideas.

VITALmaths video clips as a medium for visualisation

A mobile phone has the potential to be used as a visualisation tool because of its portability, mobility and versatility. These functions make learning ubiquitous in and out of classrooms, provide potential opportunities for collaborative learning, and enrich the learning experiences with the support of technologies (So & Kim, 2008). A joint project of Rhodes University of South Africa and the University of Applied Sciences Northwestern Switzerland, Linneweber- Lammerskitten, Schafer & Samson (2010) has established a database of freely available video clips that can be downloaded on mobile phones to explore mathematical ideas and concepts. The Visual Technology of Autonomous Learning of Mathematics (VITALmaths) project (see www.vitalmaths.com) seeks to encourage the autonomous use of its video clips as a novel medium of communicating mathematical ideas.

The features of the short video clips include being visually appealing, silent, and making use of everyday materials. The video clips are generally self-explanatory requiring minimum mathematical proficiency to interpret and conceptually understand the concepts; and can be used autonomously in any environment (ibid).

According to Linneweber- Lammerskitten et al., (2010) “the video clips encourage genuine mathematical exploration that transcends the mere mathematical content of the film by encouraging a desire to experiment, use trial and-error, formulate conjectures, and generalize results” (p. 355).

**Student teacher education in Zambia**

The Zambian National Information and Communication Technology (ICT) policy, (Zambia. Ministry of Education [MOE] 2007), recognises the importance of using technology in the teaching and learning process. There is therefore a need to capitalise on the affordances of ICT applications such as videos on mobile phones to support teaching and learning. It is thus incumbent on student teachers’ to make appropriate use of these devices in their teaching and learning. The learning activities associated with the use of mobile phones should however be learner centric, collaborative, contextual and engaging. This paper argues that the mobile phone has the potential to soften
boundaries between students’ daily life and their school life to ensure that mathematics is contextualised with their own experiences.

One of the objectives of the ICT policy in Zambia is “to provide … teaching materials for integration in the classroom for basic education, high schools, pre-service and in-service training to provide an alternative mode and facilitate access to the education materials” (Zambia. MOE, 2007, p. 19). The policy underscores the importance of ICT in schools and in teacher education institutions by acknowledging that “educational imperatives stress the need to raise educational standards by the introduction of ICT into schools and teacher training” (Zambia. MOE, 2007, p. 3).

One of the reasons cited for poor performance by learners across the Zambian mathematics education system is the lack of teaching that promotes conceptual understanding (Zambia. MOE, 2014). Kalimaposo (2010) is of the view that student teachers in Colleges of Education in Zambia are unfortunately not sufficiently exposed to teaching methods that foster conceptual understanding and the associated construction of knowledge. This paper argues that one way in which conceptual understanding in mathematics can be enhanced is by integrating appropriate technology in the teaching and learning process. The use of a mobile phone, a device that is pervasive among students and student teachers in Zambia and has the potential to be used as a visualisation tool could be one of the solutions.

Teachers’ use of technology to enhance visualisation has the potential to engage learners in active mathematical practices that include experimenting, investigating and problem solving which can all add depth to understanding (Goos, 2010). Sharples (2002) suggests that mobile technology can be an effective device for personal learning.

In my experience, most learners, who generally are young people, are very much at ease with using digital devices such as computers, video games, mobile phones and the internet. This opens many educational opportunities and ultimately implies that teachers should consider realigning their ways of teaching to take advantage of this modern technology.

Mobile technologies today are ubiquitous as a medium for communication globally, and as such the potential of mobile technology to change teaching and learning is immense (Garrison & Anderson, 2003 as cited in Ndafenongo, 2011). The opportunities that have come with modern technology call for realignment in the teaching and learning process in order to explore their educational potential. The mobile phone is pervasive, costs relatively little compared to other gadgets, is easy to use, and easy to set up to mobile networks, even in areas where the infrastructure is poor.

Despite national policy pronouncements however, not much has been done to implement ICT into education especially in primary and secondary schools. We therefore assert that this study is not only necessary but timely in the Zambian context. The study not only contributes to the existing literature,
but also provides a platform for stakeholders to discuss and hopefully find solutions to how a mobile phone, from a visualisation perspective, can be utilized in the Zambian classroom.

**The intervention with student teachers**

This study specifically investigated the personal interpretations and understanding of the experiences of eleven student teachers on their use of VITALmaths video clips on mobile phones in teaching number sense during one of their teaching practices. The participating student teachers were initially introduced and oriented to the concept of visualisation and its use in the classroom. They were also inducted to the VITALmaths video clips and their application on mobile phones. The student teachers were then asked to plan a series of lessons on number sense in which they made use of the video clips. These lessons were then implemented and video recorded for analysis as discussed below.

**The student teacher intervention in schools**

The student teacher intervention and the research study took place at four primary schools where each student teacher conducted one lesson as part of his/her teaching practice. Each lesson was based on one of the three selected VITALmath video clips. The mathematical domains and topics in focus were: sum of consecutive odd numbers, rectangular products and palindromic sums. Mobile phones were used as conduits for the videos and were availed to the learners and student teachers for those who did not possess their own.

**The research methodology**

The selection of the eleven student teachers was purposeful because they: were student teachers at the institution where the researcher is based and were willing to take part in the project (ii) were in possession of a mobile phone on which VITALmaths video clips could be uploaded, and (iii) were undertaking a primary teacher education course.

A qualitative case study methodology was adopted where the case was eleven student teachers of a public university in Zambia who taught number sense using VITALmaths video clips that were uploaded on mobile phones. The unit of analysis was the eleven student teachers’ experiences of how they used the visualisation video clips on mobile phones to teach number sense. The research instruments to gather data consisted of interviews, focus group discussions, discussions, observations, and document analysis.

The specific research questions that framed the study were:

*Research Question 1* - How can VITALmaths video clips on mobile phones be used by student teachers as a visualisation tool in the teaching of number sense?

*Research Question 2* - What enabling and constraining factors do student teachers encounter when using mobile phones to teach number sense?
Short discussion on the findings

Data was analysed by considering emerging themes that were key in the teachers’ responses of their experiences of the role that mobile phones played as visualisation tools when they were teaching their lesson.

Summary of findings
The summary of the findings with reference to the two research questions that guided this study are as follows:

Research Question 1
The videos were sometimes used in a “chalk and talk” context either at the beginning of a lesson to introduce a topic or an idea or at the end of the lesson to consolidate what had been taught. The videos were also used to enhance the conceptual understanding of number sense and as a means for the pupils to share their learning on number sense. The student teachers at times used the videos as prompts for class discussion and would often play the video clips repeatedly to reinforce an idea.

Research Question 2
The enabling factors that the student teachers identified included creation of mental pictures and diagrams as key visualisation aspects in problem solving. The video clips were easy to use and self-explanatory and provided learners with valuable ideas on a topic before it was taught in class. The videos were visually appealing and animating and a number of them suited the ability of the Grade 7 learners. Furthermore, the videos exposed learners to a variety of methods of solving the same question, increased learners’ participation, attention and curiosity and motivated them to explore

On the other hand, the constraining factors that were identified by the student teachers included; Small screen size of the phone and small font in the texts of the video. Short duration of the video clip, regulated text entry and inadequate number of phones were the other constraining factors identified. The rest of the constraining factors were inability of some phones to pause, consuming more time when using a phone as a teaching tool and distracting learning when the learners were side tracked by the technology

Recommendations

Based on the findings of this study, the following recommendations were made: Teachers should be encouraged to produce similar videos that promote visualisation on various Mathematics topics at various levels based on the school syllabi; Conduct awareness and sensitization to demystify the wholesome negativity associated with use of mobile phones in Zambian schools; The mobile phone should be utilised as a teaching and learning tool in the classroom; Video clips that promote autonomous learning should be incorporated into teacher education programmes; Teachers and learners should use video clips autonomously and independently; Learners should be given adequate
time to explore the videos; Adequate number of mobile phones should be sourced to be used in the teaching and learning process. and finally, the mobile phone used should have bigger screens, bigger fonts and graphics, and long battery life.

Suggestions for further research
Since the research was only done on a small scale, we recommend the following: Conduct further research on how mobile phones could be used effectively across the teacher education curriculum in Zambia; Explore research possibilities in the incorporation of mobile technology into the school curricula that promote autonomous learning of Mathematics and other subjects; Conduct research with more research sites and a bigger sample size for the findings to be generalized to a wider context and finally to conduct research with other ICT devices, not only mobile phones.

Conclusion
This is a synopsis of our research study. It provided a brief overview of my study and a summary of the findings based on the study. It presented a brief discussion of the significance of the study, provided recommendations based on the research findings, and suggested areas for future research.

REFERENCES


Research shows that current mathematics classrooms are characterised by the use of various teaching aids to help learners understand certain mathematical concepts and develop a deeper conceptual understanding (Jenkins, 1957). At times, technological applications are used to reinforce mathematics concepts and aid understanding and also enable the teacher to move towards a more learner-centered approach allowing the learner to see mathematics in a less abstract way which is applicable in the elementary school level (Roblyer and Doering, 2013; Ferrini-Mundy and Breaux, 2008). Studies have shown that early mathematics learning and reading skills are a great predictor of later achievement in the learner’s academic life (Duncan et. al, 2007). The Curriculum and Assessment Statement (CAPS) Grade 1 to 3 (2011, pp. 10) policy document in South Africa emphasises that “In the early grades children should be exposed to mathematical experiences that give them many opportunities to do, talk and record their mathematical thinking”. Emphasis on conceptual understanding and higher order thinking at early age can assist in ensuring that learners have a good foundation for concepts that will be taught on higher grades.

One of the key ingredients to successful mathematics learning is communication within the mathematics classroom, and this is possible through language. The connection between mathematics and language cannot be ignored, especially in the context of South Africa where multilingualism is the order of the day, as mathematics is taught in and through language (Barwell, 2009; Boulet, 2007; Pimm, 1981). Barwell (2009) argues that the learner’s proficiency, or lack thereof, in the language of learning and teaching (LoLT) plays a major role in their mathematics performance, compared to their monolingual peers. South Africa is one context which has historically been affected by Apartheid, with effects being experienced by the country to this day (Phakeng & Essien, 2016). In recognition of the necessity to ensure equal access to education for all, the language in education policy (1996) has made provision for learners to receive instruction in their mother tongue supporting conceptual growth as well as ensuring that the difference between the learners ‘home language and the language of learning and teaching (LoLT) is minimal. Despite this allowance there seems to be a trend in which the first three years (Grade 1-3) learners learn and are taught in their home/first language, however in Grade 4 the LoLT changes into English (Manyike, 2013).

In this current study an investigation is underway to determine how the use of a Mathematics App developed by and called onebillion© enables the teaching and learning of mathematics in classroom
situations, from a language and in particular multilingualism perspective. One way in which this has been achieved is by the isiZulu home language provision that is offered by the App in order to enhance mathematics access to the learners in a certain social context who are not English first language speakers. This App focuses on core mathematics concepts for the first 4 years of schooling (Grade R to 3). The App was originally developed in English language and has now been translated into African languages (isiZulu in the case of the current study). Translating the mathematics register from one language to another is not a straightforward enterprise. The extent to which language issues can be found in Mathematics Applications that have been translated from a developed language to a developing language has not been an explicit focus in research. This study sets out to investigate this phenomenon. To achieve this, I will focus on the onebillion© App centering on the Mathematical language/register used in the App by looking at how the isiZulu mathematics language in the App compare to the language found in the Curriculum used by the teachers and the learners. I will also engage with the following questions: What is the teachers’ perception of the isiZulu as it is used by the App? What has the App enabled the teachers and learners to understand better? And what language issues are embedded in the use of the App?

The theoretical framework that is used to inform this study is that of Engelström (1999) Expansive Activity Model. This theory has its etymology in Vygotsky’s (1978) work on mediation, and the work of Leontev on action and activity highlighting division of labour. The main idea behind the expansive activity model is that when analysing how children come to know it is important to note the complex context this happens in. The child does not come to know on his/her own but in the context of the society in which s/he is part of. The different components that construct the learning context are presented in the below diagram in Figure 1 (Engelstrom, 1999).

![Figure 1: Engelström’s Expansive Activity Model](image)

In seeking for in-depth description and understanding of the language nuances associated with the App, from the teachers and learners’ experiences, semi-structured interviews and classroom observations have been selected as the preferred data collection methods (Yin, 2016). Two Grade 1 teachers and seven randomly selected Grade 1 learners will be my sample. Furthermore, I intend to
review to the documents that are used in the traditional mathematics classroom (the teacher and learner materials) as well as the App itself. From this analysis I hope that it will be clear as to whether there are any inconsistencies between the mathematics register that the learners encounter in the mathematics classroom and that encountered in the App (Basit, 2010).

The data that will be collected will be analysed using Hardman’s (2008) framework (Table 1) which has been adapted to fit the context of the current study.

**Table 3: An adaptation of Hardman’s (2008) Table 1 AT Cheklist**

<table>
<thead>
<tr>
<th>Concept</th>
<th>Questions to ask when analysing data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object</td>
<td>What is the object/focus in using the App?</td>
</tr>
<tr>
<td>Instruments (tools)</td>
<td>What does the teacher say about the ease of using the App from the teacher’s perspective? And the learners?</td>
</tr>
<tr>
<td></td>
<td>What does the teacher/learner say about the isiZulu language used in the App?</td>
</tr>
<tr>
<td></td>
<td>Is there any inconsistencies in the isiZulu Mathematics register used in the App and the one used in the learning materials?</td>
</tr>
<tr>
<td></td>
<td>Does the teacher have to explain to learners how to use the App?</td>
</tr>
<tr>
<td>Outcomes</td>
<td>Have learners demonstrated better understanding of the mathematics concepts they have engaged with in the App?</td>
</tr>
<tr>
<td></td>
<td>Can this be proved by the teacher, if yes, How?</td>
</tr>
<tr>
<td>Division of Labour</td>
<td>What responsibilities do teacher/learners have when working with the App?</td>
</tr>
<tr>
<td>Community</td>
<td>What community is involved in the leaning of mathematics when using the App?</td>
</tr>
<tr>
<td>Rules</td>
<td>What kinds of rules: instructional rules=evaluative/pacing rules are present?</td>
</tr>
<tr>
<td></td>
<td>What kind of social order rules=disciplinary/communicative interaction rules are present?</td>
</tr>
</tbody>
</table>

Together these questions will help me map the mathematics App to the Curriculum and highlight the teachers’ and learners’ view of the language as used in the App which in turn could have implications on the mathematical understanding of the learner.

The contribution this research is intended to make is that, whilst mathematical content is often critically scrutinised before a roll out of an intervention, it is important that we do not overlook the intricacies associated with language as well as the role which language can play in ensuring that the learning that is offered is not diluted or impeded.

**References**


A PRELIMINARY REPORT OF THE PILOT STUDY FOR THE PROPOSED ONLINE PGDE PROGRAMME FOR MATHEMATICS, SCIENCE AND COMPUTER STUDIES AT THE UNIVERSITY OF BOTSWANA

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Abstract
This study was designed to pilot the proposed online Postgraduate Diploma in Education (PGDE) programme for computer studies, mathematics and science education at the University of Botswana. A Framework to guide the implementation of the online PGDE project and to pilot the project was designed. Students completed questionnaires to provide feedback about their experiences from participating in the online course. The preliminary results of the pilot revealed positive students’ experiences and views and indicated the nature of support required. The required support for students were mainly about accessibility of internet outside campus as well as other technological support. The results served as the basis for the development of a Toolkit to use in making decisions in embarking on the online mode of delivery through Moodle. However, further research is needed since the course instructors’ experiences and views.

Introduction

The University of Botswana (UB) embarked on a project to deliver the PGDE programme through an online mode. A Team from relevant departments developed a Framework to implement the online programme. The Framework adopted the Wrap-Around-Model (WAM) instructional mode. Characteristics of WAM are that it:

- Utilizes tailor-made materials (e.g. Books, CD-ROMs, Videos, study guides, etc.) and activities wrapped around these
- Allows for e-Learning materials to be combined with existing resources to create ‘blended’ model
- Includes online discussions and interactions
- Allows for Group work
- Is learner-centred
- Changes the role of the lecturer to be that of a facilitator

A blended approach was chosen to cater for course activities that require face-to-face classroom interactions like practical activities.
Furthermore, the team outlined how to implement the online PGDE considering development of materials after training course developers, required resources within and outside campus, and to pilot using enrolled students for August 2016 Academic year. However, a pilot study plan was devised for the August 2017 Academic year intake. This included formulation of the aims of the pilot, theoretical framework, methodology and procedures for data collection, analysis, and modalities of feeding back into the project. The main aim of the pilot study was to develop a Toolkit. A Toolkit is a decision-making system, designed to facilitate the identification of implications or recommend suitable approaches based on the information and assumptions elicited from the user, (Conole et al, 2004, pp 22). Toolkits can be employed by practitioners to make use of inferences from the pilot exercise, in making informed professional decisions about what changes are necessary in the programme being proposed. This allows gauging the quality of the proposed programme and to investigate implementation logistics including effectiveness and accessibility of course materials. Toolkits are meant to serve a variety of purposes like “a process of enabling practitioners to evaluate their own practice”.

Moodle as a technological platform, requires both the course instructors and students to be acquainted with the platform that they were not necessarily familiar. This necessitated that course instructors were to be trained and that all the technological support for students was understood. All these factors necessitated that a pilot study be conducted before the online PGDE programme could be implemented.

Research questions
The pilot study aimed to address the following research questions:
1. What were enrolled PGDE students’ views of learning through the online mode of delivery?
2. What technological support did students require to participate successfully in the online PGDE programme?

Literature review
Technology is viewed as a tool that has potential minimize a number of challenges in almost all sectors of life, education included. These technologies often eliminate distance related issues and other factors through flexibility particularly in the education sphere which is often restricted classroom boundaries. However, these restrictions have in turn resulted in issues of lack of accessibility of learning, particularly at high education level that is often needed by individuals already with some form of employment. With the emergence of technology, education can be accessed anytime, anywhere if online mode of delivery is made available. The UB, in recognizing the importance of online courses in attracting and enticing potential students, has made Learning Management platforms such as Moodle available for meeting the needs of nontraditional learners found within the country. As stated by researchers, higher education institutions can begin to offer a number of distance-education opportunities to meet the needs of increasingly high numbers of these nontraditional students (Khan, 1997; Kearsley, 2000) through online programmes. It is worth
noting that the use of online programmes has been on the increase due to the rise in technological advancements. This calls for quality checks to guard against lowering the standard of education. It has been reported that several online distance-education courses failed to meet quality standards set by researchers and institutions (Garrett, 2004; Oliver, 2005). This is a concern that is worth noting by online course developers.

It is essential for online programmes to be piloted for the evaluation and corrective measures to be employed. Searles (2012) proposed a way around this ensuing problem for students to following in making decisions for enrolling in an online programme. Much as this precautionary measure is suggested for students, programme developers should also ensure that they develop high quality online programmes underpinned by the needs of their societies. This necessitates that Instructional designers be capable of doing a good job. As state by Beirne (2018) faculties are under pressure to offer online programmes due to the popularity and accessibility of new technological tools. UB is taking steps in that direction by taking advantage of the new technologies. This particular study is meant to achieve the needs of Botswana where the teaching of mathematics, computer studies and science subjects is still considered as a scarce area. National policies such as the Education Training Sector Strategic Plan 2015-2020 (Republic of Botswana, 2015) also support the move to increase accessibility of education programmes checked for quality assurance, hence this pilot study.

Methodology

The study aimed at collecting descriptive data through student questionnaires. The questionnaire comprised of Likert type of items and unstructured items for participants to give feedback on their views that may not have been catered for in structured questions. A total of 22 students participated, 4 mathematics, 6 science and 12 computer studies education. The data was analyzed on students’ views about the following categories:

- General course structure
- Instructor actions and strategies
- Learning/teaching methods, tasks and assignments
- Assessment methods
- Technological and support services
- Experiences with the LMS (Moodle)

The questionnaire was administered by each course instructor but analyzed collectively for a shared understanding and transparency of the analysis procedure.

Findings and conclusions

Tally marks were used to capture responses for each of the questions requiring responses from Strongly Disagree, Moderately Disagree, Slightly Disagree, Slightly Agree, Moderately Agree and
Strongly Agree. These were compiled to tables like the one below on ‘Good encouragement of research skills development’ and ‘Good encouragement of digital literacy development’ items:

<table>
<thead>
<tr>
<th>Item category/Items</th>
<th>SD</th>
<th>MD</th>
<th>SD</th>
<th>SA</th>
<th>MA</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Learning /teaching methods, tasks and assignments</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good encouragement of research skills development</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Good encouragement of digital literacy development</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td><strong>Technological and support services</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I had good access to technical staff for support and help</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>6</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Speed of accessing the LMS and its resources is good</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>8</td>
<td>7</td>
</tr>
</tbody>
</table>

Generally, the findings revealed that participants had good experiences and also had no challenges in accessing the technological and technical support.

These results served as a good indicator of the quality of developed learning materials, technological support and accessibility for running the project. However, since the developed methods were not for all topics within each course, further research is required. In conclusion, the results formed the basis for the development of the Toolkit that the pilot study intended. Also, the blended approach enabled quality teaching and learning for enrolled students.

**References**


Conole et al, 2004


EXPLORING MATHEMATICAL HABITS OF MIND IN EUCLIDEAN GEOMETRY GRADE 12
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Abstract
The purpose of the study is to use concept habits of mind to explore South African Grade 12 learners’ understanding of Euclidean geometry through document analysis of NSC-Examination, Grade 12 past questions papers. The past papers analysed for the study are as follows: Nov 2014, Feb/Mar 2015, Nov 2015, Feb/Mar 2016 and Nov 2016. These are the Department of Education (DoE) question papers regulated by UMalusi the Quality Assurer. Learners’ understanding of geometry concepts, including metacognition, were investigated using explicit and implicit questions in Euclidean geometry. Data for the study was collected through document and/or content analysis, a diagnostic analysis report from the DoE. The study concludes that concept habits of mind is an effective tool to explore learners’ metacognition and knowledge of the geometric concepts. The report concludes with recommendations for classroom practice, the adoption and implementation of the concept habits of mind into teaching practices.

Key Words: Concept(s) Euclidean geometry, Habits of Mind, Metacognition, Implicit and Explicit, Diagnostic Analysis, Document and/or content analysis, Conceptual Inquiry Study.

BACKGROUND TO THE STUDY
This research focuses on using habits of mind to solve problems in Euclidean Geometry. Habits of mind can be described as knowing how to behave intelligently when you don’t know the answer. It means having ways to find solutions when confronted with problems, the answers to which are not immediately known: dichotomies, dilemmas, enigmas and uncertainties. Furthermore, habits of mind are defined as thought processes repeated over time and these habits of mind are not hierarchical in their development. Cuoco (2008) views habits of mind as modes of thought over and above mathematics content knowledge or its application to solve problems. They are regarded critical for thinking about the quantitative or spatial perspectives and for thinking about the mathematical content itself. Lim and Selden’s (2009) views are that these include ‘pattern-sniffing, experimenting, formulating, tinkering, inventing, visualizing, and conjecturing’(p.1576). They can be classified as new knowledge learnt resulting into one’s metacognitive (thinking about one’s own thinking) competencies when doing mathematics or solving mathematical problems.
These authors see habits of mind as having much potential in helping in solving high school Euclidean geometry.

**Why use habits of mind in Euclidean Geometry?**

Euclidean geometry has a huge significance in the Curriculum of the Assessment Policy Statement (CAPS) mathematics curriculum. Euclidean geometry also plays a major role in the mathematics content as a base and feeder for topics such as Trigonometry, Analytical geometry including calculus. Learners cannot solve geometric problems related to those topics without a thorough knowledge and understanding of Euclidean geometry. Habits of mind are a way of processing one’s thinking in a problem solving milieu. Habits of mind ensure that a mathematics course is organized around ways of thinking rather than results.

Consequently, it ensures that one benefits in developing genuine mathematical ways of thinking which produces mathematical power and other important domains other than mathematics. Habits of mind are described as mental habits which encourage learners to make sense of mathematics and be able to navigate mathematics (Cuoco, Goldenberg & Mark, 1996).

**PROBLEM STATEMENT**

The diagnostic analysis results between 2013 and 2016 show an increasing poor pass rate in Euclidean geometry in comparison to Analytical geometry and Trigonometry. It is a common knowledge to those in mathematics education circles that congruency geometry, for example, is a problematic area for our learners (Pillay, 2006). Matriculation examiners’ reports regularly draw attention to the fact...
that Euclidean geometry is a most problematic area (Pillay, 2006). De Villiers (1997) also refers to the fact that the worst performance is produced in geometry rather than in algebra. In agreeing with De Villiers, as mathematics educators and researchers we recognize Euclidean geometry as one of the most problematic areas in the mathematics curriculum. Outlined below, is the diagnostic analysis report for 2016 in

![Average performance per question paper 2: 2013-2016](image)

Figure 2: (Average performance per question paper 2: 2013-2016).

It is attested in the DoE (Diagnostic analysis report, 2016) extracted between 2013 and 2016 that a decline in geometry grade 12 overall performance persists. A performance comparison of paper 1 and 2 shows a non-progressive performance on paper 2 results with a pass rate below 60% for Euclidean geometry. The above scenario raises a huge concern that prompts an interest to come up with an approach to improve learner outcomes on the topic.

The following research questions are posed:

**Main Question:** What are the most common habits of mind used in assessing Euclidean geometry in grade 12?

**Sub – Questions:**
- How will metacognition be interrogated as a phenomenon, knowledge and cognitive process required in habits of mind?
- What type of a hypothesis can be generated within the study habits of mind?

**RATIONALE**
Habits of mind as a study embrace methods and techniques that learners may use to learn Euclidean geometry and solve associated problems in Grade 12. The study is worth pursuing as it brings new ideas and approaches to understanding geometric concepts. The study also focuses on Driscoll’s (1999) assertion that “Fostering Geometric Thinking” provides a framework of productive mental habits relevant to Euclidean geometry.

Habits of mind as a study carries a huge significance for teachers and researchers as it is a novel approach in the understanding of geometric concepts. It helps one to analyze questions, not only in geometry, but in other mathematical areas with a deeper understanding. The understanding of habits of mind may also have a positive impact on the grade 12 learner competency and ultimate performance.

THEORETICAL AND CONCEPTUAL FRAMEWORK

Habits of mind are productive ways of thinking that support the learning and application of formal mathematics. A key point about learning mathematics is about developing these mind habits (Goldenberg, Cuoco & Mark, 1998). Furthermore, Cuoco, Mark and Goldenberg claim that they believe that academic experience in high school should be used as an opportunity to help students develop what they have come to call “good general habits of mind”. Goldenberg, Cucco and Mark (1998) highlight this notion of habits of mind, equating it with mathematical power. People with mathematical power perform thought experiments, invent things, look for invariants or patterns, make reasonable conjectures, describe things both causally and formally, think about methods, strategies and processes, visualise things and seek to explain why things are as they see them.

Habits of mind have two characteristics: the “thinking” characteristics and the “habituated” characteristics. In addition, habits of mind are reflexively related to classroom practices. Cuoco, Goldenberg and Mark (1996). This statement means that habits of mind are ontological and they have a historical background, basically they are done without any thought given, they happen involuntarily due to their nature of being “habituated”. In our view, habits of mind fall within a social constructivist/interpretivist framework underpinned by understanding, which is formed from the historical background and mental or mind -categorized way of thinking, i.e. visualising and pattern sniffing, experimenters, tinkerers and so forth.

In understanding this conceptual framework for habits of mind, I refer to the first part of this research report as follows: Background of the study on the following sub- headings a) Context b) Problem statement c) Purpose statement and finally to the Appendix, for further data which form part of table 2. Consequently, the above shows a summary of the theoretical and conceptual framework adopted as an analytical tool, to organize ideas around our research study for habits of mind.

LITERATURE REVIEW

Concept (Euclidean Geometry)
Firstly, the concept of Euclidean geometry comes from a branch of science called geometry which is the work of Euclid’s elements. Euclid’s book “Elements” has been the main influence on geometry education. It was used from the 14th century in European universities and from the 19th century in schools. France and Germany have deviated from Euclid’s work, opting for a more applications - orientated approach, while British secondary schools have continued to teach Euclidean geometry (Human & Nel, 1978). In South Africa, the approach is more formal than in other countries (Usiskin, 1987). We can identify two reasons for the importance of Euclid’s elements in understanding the foundations of science: its structure and the certitude of its results. Euclid’s elements solved an important problem, for instance, when we have a large body of knowledge, such as we have in geometry, how we are to organise the knowledge becomes fundamental in Euclidean geometry; for instance, simple things in geometry: the sum of the angles of a triangle are always 180 degrees.

The above implies that in Euclidean geometry, there are habits of mind which can be used in solving geometry problems. Therefore, these habits forms knowledge that comes into cognitive and becomes metacognition once learnt and conceptualized, therefore some may habits become a invariant, which means there are things that can be conceptualized in that way. Euclid asserts that as our knowledge grows, we need to have ways to organize it, so that we capture all the truth that we want and do not let in things that don’t belong there. Euclid’s employed a profound method called deductive systematization, of which his elements were structured according to a series of propositions for example; definitions, axioms, postulates, theorems, premise and conclusions. Once the structure is adopted, the knowledge of what really belong in geometry gets reduced to matters of deductive inference, whereby a deduction must be made in terms of what is truth and what is not in Euclidean geometry, while applying Euclid’s elements.

2.2.3 Trends and Debates

RESEARCH DESIGN AND METHODOLOGY

Research Design

For this research a conceptual method of inquiry, i.e. a research that will proceed on theoretical level and works with texts and extensive review of literature will be used. It is particularly concerned with defining, clarifying and interrogating a concept of representation that is used in geometry by the examiner to that of a memorandum.

Sample

The sample used is the analysis of the past grade 12 question papers and memorandum. Examining the memorandum used for the questions and compare that with the examiner to see if there is a difference and what is different or the most common habits of mind that were used. The conceptual research addresses the ontology and the epistemology of the research. The ontology is the habits of mind that we are considering and the epistemology which is the outcome result of the analysis of the habits of mind. The study will employ a structured purposive sampling due to document analysis, therefore it can be a narrative data analysis.
Data Collection

Habits of mind are described accordingly and examples are provided from different past grade 12 papers, for instance November 2014, February/March 2015 up to November 2016 as a justification of a description of a habit. A table form method will be used to first name a habit of mind using a code i.e. (HoM1), followed by a definition of that particular habit, an example in a form of a figure and finally a description or a narrative of the analysis from the example figure provided. A diagnostic report from DoE (Department of Education) for 2016 used as part of data collection to analyse and compare the results of those previous Grade 12 performance rates.

ANALYSIS

When analysing data, I was looking for explicit and implicit habits of mind in the questions from the sample which was the grade 12 past question papers. The analysed question papers have shown that there are more implicit habits of mind in Euclidean geometry in comparison to explicit ones. From the following question papers, November 2014, February/March 2015, November 2015, February/March 2016, November 2016, it was established that there are also common habits of mind that are used by the examiner when assessing grade 12. Furthermore, I mention that metacognition is used to look for explicit and implicit questions. The type of thesis used was analysing the documents to get to a conclusion that I have arrived at. The criteria that were used are as follows: the first table is for implicit and explicit questions in Euclidean geometry. The second table, entails geometric habits of mind and its characteristics. On the third table are characteristics and their definitions of habits of mind. On the fourth table are definitions of habits of mind and its description which was used as a focus area to analyze each habits of mind and furthermore to establish the commonly used habits of mind in Euclidean geometry. Furthermore, I looked at the implication of the study for future performance. Data analysis illustrated in FIGURES below:

<table>
<thead>
<tr>
<th>HoM I, II, III and VI</th>
<th>Question (Nov 2014)</th>
<th>Description or Narrative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visualiser and recall are the two habits of mind that are required to determine that is an invariant and the angles is 90 meaning it will remain the same, it will not change due to being midpoint of chord CD. One has to construct a mental picture and</td>
<td>Determine with reasons, the sizes of: 1. $\hat{F}F$ 2. $\hat{ABC}$</td>
<td>A, B, C and D are explicit and is an invariant and it is implicit, subtended by a diameter which is in semi-circle. F is the midpoint of chord CD and is an explicit angle. and AC is implicit.</td>
</tr>
</tbody>
</table>
recall. As for AC, a habit of mind to be used is seeking invariants i.e. AOD is a diameter and it is an invariant since it makes AC, in semi segment. And angle becomes supplementary to AC.

However, is implicitly equal to 90 and is explicitly equal to 30 therefore is 60 sum of interior angles of a triangle equal to 180.

<table>
<thead>
<tr>
<th>HoM I- X</th>
<th>Question (Feb/Mar 2015)</th>
<th>Description or Narrative</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Experimenter, recalling, reasoning with relationship and continuity and visualizing</td>
<td>Learners performing thought experiment, so that, without writing anything down they can give evidence for their answers</td>
<td>A = 48 makes O angle at the centre equal to twice angle A at the circumference which makes O = 96 To get the value of then a learner look at what is explicit from the information given and what was implicit in terms of O which is now explicitly proven. Learner can therefore use that relationship and continuity.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Question Paper Analyzed</th>
<th>Explicit Habits of Mind</th>
<th>Implicit Habits of Mind</th>
</tr>
</thead>
</table>
| **November 2014**  
Question 8.1.1 and 8.1.2, 8.2.1 and Q 8.2.2 | Visualiser and Recall theorem (at centre = twice at circumference) and sum of in. Visualiser and Recall – theorem (opposite of a cyclic quad are supplementary). | Thought experiment/Intellect chant and reasoning with continuity and reasoning with relationship in Q8.1.1 i.e. Intellectual chant/thought experiment in 8.2.2. Seeking invariants for 8.2.1 i.e. reasoning with relationship for 8.2.2 (opposite of a cyclic quad are complementary) i.e. AC + = 180. Seeking invariant in 8.3.1a) and 8.3.2. Tangent Radius is an invariant and reasoning with relationship is tangents from common points are equal in length. |
| **November 2014**  
Question 8.1.1. 8.1.2 and 8.2 | Visualiser and Recall theorems (at centre = twice at circumference) and sum of in. For 8.1.1. and 8.1.2. (opposite of a cyclic quad are | Intellectual chant and reasoning with relationship and continuity and = 2 in 8.1.1. Explanation and reasoning with relationship in 8.1.2; + (opposite of a |
supplementary). Analyse geometric shapes.
Recall and logical connections
Recall and visualiser of algebraic calculation.
Recall theorem and Visualiser (Line from a centre to a chord bisect the chord or perpendicular to chord) for 8.1.1, 8.1.2

Reasoning with relationship for 8.2.
Seeking invariants of parallel lines in 9.1, reasoning with connection in same segment) for 9.2, 9.4 and 9.5 it is reasoning with continuity and logical connection.
Algebraic calculation and invariant of a semi-circle in 10.1. Proportionality, reasoning with relationships in 10.2.1 and algebra calculation. Proportionality reasoning in 10.2.3, abstract and breaking things into parts in 10.2.4.
Make logical connections and seek invariants for parallel lines for Q 8.1.1 8.1.2. Intellectual chant/Thought experience

Figure 3: Explicit and implicit habits of mind

DISCUSSION
Considering the HoM conceptual framework (Goldenberg, Cuoco & Mark, 1998) we note that some questions require explicit habits of mind whereas others require implicit habits of mind. Reasoning with relationship or logical connections and proportionality reasoning. As for reasoning with continuity the Nov 2015 question 8.1.1 based on the idea that opposite angles of a cyclic quadrilateral are supplementary. An example of logical connections was on recalling of two theorems and connecting them to answer a question for example 8.1.1 and 8.1.2. In this case if we have angles 2x at the centre of the circle, it subtends an angle of x at the circumference. If 2y is also at the centre of the circle, it also subtends y the opposite side of the circumference. Then since 2x+2y=360 degrees so x+y must be half of that which is 180 degrees prove the result that the sum of opposite sides of a cyclic quadrilateral adds up to 180 degrees. This is termed an intellectual chant or logical connection habit of mind. This is implicit because it’s not clear but it’s something they need to establish or seek. The explicit habits would be for example recalling a result for example a theorem. With seeking invariants is exemplified by the result that any angle subtended by a diameter on the circumference will be 90 degrees or that a tangent is always perpendicular to a radius. The question 9.1 and 9.2 of Feb/march 2015 paper 2. In this question, they recall the ta-cord theorem and that to prove a result. Here the HoM of visualisation also is required as well as seeking invariants as explained above. In some cases, visualisation means that learners need not only recall what they visualize but also need to construct as part of extended visualisation to solve or prove a Euclidean geometry problem. Thus, implicit and explicit habits of mind work closely together in order for one to solve most Euclidean geometric problems. Thus, metacognition which requires ones thinking about ones’ thinking combines explicit and implicit HoM.

The hypothesis we generate is that if learners are able to link explicit and implicit habits of mind when solving geometric problems, they can easily manage to solve such problems.

CONCLUSION AND RECOMMENDATIONS

In response to our other research questions, our answer is certainly that there are common habits of mind in Euclidean geometry. They are explicit and implicit habits which are used to answer questions, implicit habits are more than the explicit ones as mentioned prior. Metacognition can be used in understanding these habits and learners can use it as a learning tool to explore habits of mind in Euclidean geometry such as seeking invariants, reasoning with relationship and continuity and applying thought experiment and intellectual chants. Furthermore, I am certain that the understanding of habits of mind can yield positive results on the grade 12 paper 2 pass rates in future. Moreover, there will be a narrative data analysis that can be used by others to improve the performance rate in grade 12 globally. Consequently, it will align learners understanding to that of the examiner (DoE) when they are being assessed as well as equip them with the best techniques, skills and ways of thinking around Euclidean geometry. Habits of mind will eventually close the gap of poor performance created in the past due to lack of extensive research and analysis of such habits of mind in geometry.
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A SYSTEMATIC REVIEW AND META-ANALYSIS OF MATHEMATICS EDUCATION RESEARCH IN SAARMSTE: IMPLICATIONS FOR FURTHER RESEARCH

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ABSTRACT
The study provided a comprehensive identification of annual trends in mathematics education Long Papers presented at the Southern African Association for Research in Mathematics, Science and Technology Education (SAARMSTE) conference from 2012 to 2018. The analyses are based on 109 mathematics Long Papers presented at the SAARMSTE conference from 2012 to 2018. The analytical framework and levels of classification used were based on the concept of ‘mathematics education as a social process’. We found that Long Papers presented during this period contributed mostly to mathematics education research studies at the ‘institutional’, ‘pedagogical’, and ‘individual’ levels. These results imply that the amount of studies at the ‘cultural’ and ‘societal’ levels should be increased for the next ten years and that the choice of these levels has undergone changes since 2015.

Keywords: mathematics education research, SAARMSTE, Long Papers, meta-analysis

INTRODUCTION
Since the Southern African Association for Research in Mathematics, Science and Technology Education (SAARMSTE) was founded, Long Papers, presentations, Short Papers, and Snapshots have been presented for more than ten years. The aim of SAARMSTE is to advance research in mathematics, science, and technology in Southern Africa (SAARMSTE web, 2018), and it has contributed towards building research communities to develop African research capacities both within and outside these areas. This article’s meta-analysis identifies mathematics education research trends that have emerged in the community, where weak domains or issues are dealt with (Iwasaki & Otaki, 2015). Thus, it analyses recent trends in SAARMSTE papers and provides comprehensive and annual trends in mathematics education research Long Papers presented between 2012 and 2018.

LITERATURE REVIEW
Meta-analysis of SAARMSTE conference papers has not been conducted so far. However, in the Japanese context, a few studies have meta-analysed trends in certain areas of mathematics
education. For instance, Otani (2017) analysed the characteristics of Japanese studies related to statistics. Otaki and Iwasaki (2018) and Iwasaki and Otaki (2015) also focused upon dominant trends in Japanese mathematics education conference papers. These studies revealed the characteristics of Japanese mathematics educational research communities, but they did not analyse similar mathematics education papers presented in international conferences. This article investigates such dominant trends in international conference papers.

THEORETICAL FRAMEWORK AND METHODOLOGY

The analyses are based on 109 mathematics Long Papers published at the SAARMSTE conference from 2012 to 2017. The authors carefully chose this period due to the clear demarcations, in terms of proceedings, among Long Papers in mathematics, science, and technology that were introduced in 2012. We also utilised the analytical framework and the levels of classifications developed by Iwasaki and Otaki (2015). Iwasaki and Otaki focused on the concept of ‘mathematics education as a social process’, which was based on a concept promoted by Alan Bishop (cf. Bishop, 1991). Bishop (1991) originally cautioned that mathematics education had paid too much attention to the acquisition of mathematics techniques. Claiming that it was necessary to devote attention towards the socio-cultural aspects of mathematics, he suggested the concept of five significant levels: cultural, societal, institutional, pedagogical, and individual (Bishop, 1991, pp. 13-14; Bishop, 2010). Setting level is a useful lens to analyse the research theme of each paper and reveal dominant trends.

The mathematics Long Papers were divided into seven levels: (a) cultural, (b) societal, (c) institutional, (d) pedagogical, (e) individual, (f) meta-aspect, and (g) others. The levels (f) and (g) were added by Iwasaki and Otaki (2015) to cover all levels of mathematics education research. The details of the levels are shown in Table 1.

<table>
<thead>
<tr>
<th>Levels</th>
<th>Theme of the paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultural</td>
<td>Mathematics as culture and its nature; Cultural succession and creation related to mathematics education</td>
</tr>
<tr>
<td>Societal</td>
<td>Mathematics education in a certain country or era during a particular period</td>
</tr>
<tr>
<td>Institutional</td>
<td>Intended curriculum, Pedagogical content knowledge (PCK), teachers’ belief and identity</td>
</tr>
<tr>
<td>Pedagogical</td>
<td>Teacher’s instruction, teacher and pupil/student interaction</td>
</tr>
<tr>
<td>Individual</td>
<td>Learners’ understanding or learning</td>
</tr>
<tr>
<td>Meta</td>
<td>The subject of meta research is research itself.</td>
</tr>
<tr>
<td>Others</td>
<td>Other than those above</td>
</tr>
</tbody>
</table>

(Iwasaki & Otaki, 2015)

Each paper title was segmented into nouns and adjectives and classified based on the level of the segments. Levels were determined through the following procedure.
(1) The terms appearing in each title are first classified based on seven levels, and the levels present in each paper are determined based on the appearance frequency of the terms.
(2) If the levels are not determined in (1), refer to the sub title.
(3) If the levels are not determined in (2), refer to the abstract.
(4) If the levels are not determined through the abovementioned procedure, the paper is classified into other levels.

One study author was tasked with classifying each paper based on the appropriate level.

ANALYSIS AND FINDINGS

The analysis revealed a comprehensive picture of the annual changes in the classification of major or minor levels. These comprehensive results are shown in Table 2.

<table>
<thead>
<tr>
<th>Level</th>
<th>Cultural</th>
<th>Societal</th>
<th>Institutional</th>
<th>Pedagogical</th>
<th>Individual</th>
<th>Meta</th>
<th>Others</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of papers</td>
<td>0</td>
<td>8</td>
<td>30</td>
<td>36</td>
<td>29</td>
<td>5</td>
<td>1</td>
<td>109</td>
</tr>
</tbody>
</table>

The results showed that the ‘institutional’, ‘pedagogical’, and ‘individual’ levels accounted for more than 90% of the Long Papers, with none at the cultural level. The number of papers at the societal andmeta levels was also low. Example classification terms are shown in Table 3.

<table>
<thead>
<tr>
<th>Cultural</th>
<th>Societal</th>
<th>Institutional</th>
<th>Pedagogical</th>
<th>Individual</th>
<th>Meta</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main terms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathematical Literacy</td>
<td>Textbook</td>
<td>National Mathematics Examinations</td>
<td>Teaching strategy</td>
<td>Discourse</td>
<td>Classroom instruction</td>
<td>Intervention</td>
</tr>
<tr>
<td>South Africa</td>
<td>Lesson study</td>
<td>Continuous professional development</td>
<td>Problem solving approach</td>
<td>Teaching material</td>
<td>Student error</td>
<td>Students’ belief</td>
</tr>
<tr>
<td></td>
<td>PCK</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Next, Table 4 shows the chronological order, and Figure 1 shows the ratios for every year.

<table>
<thead>
<tr>
<th>Table 4. Analysis in chronological order</th>
</tr>
</thead>
</table>

195
Figure 1: Bar chart depicting the chronological change

Figure 1 shows that the ‘meta’ level existed until 2015. The ‘societal’ level only appeared in 2015. Except for the fact that there seemed to be nothing regarding the ‘individual’ level in 2017, Figure 1 shows that there were mostly articles on the ‘individual’, ‘pedagogical’, and ‘institutional’ levels. Following these results, as the annual changes were anticipated, correspondence analysis was conducted in Table 4. The analysis did not include ‘cultural’ and ‘others’ because the frequencies of the two levels were quite low (e.g. 0 and 1) when compared to the other five levels, as shown in Figure 2. The contribution ratios of the first axis and second axis were 0.412 and 0.376, respectively.

Furthermore, cluster analysis was conducted on each coordinate, as shown in Figure 3, which compares the years and levels. Figures 2 and 3 indicate that there was a tendency to use ‘meta-analytical’ and ‘individual’ levels from 2012 to 2014 and that there was a focus on themes related to the ‘individual’, ‘pedagogical’, and ‘institutional’ levels.
CONCLUSION

This article did not cover all the proceedings, including Short Papers and Snapshots; these could be subjects for further analysis. However, it revealed that Long Papers focused upon the ‘institutional’, ‘pedagogical’, and ‘individual’ levels, implying that the number and quality of mathematics education research studies at the ‘cultural’ and ‘societal’ levels should be increased, as suggested by Bishop (1991). In addition, it shows that the tendency to choose these levels has undergone significant changes since 2015.
References

DEVELOPMENTAL JOURNEY OF PRE-SERVICE TEACHERS OF MATHEMATICS, SCIENCE AND TECHNOLOGY: FROM PARADIGMS TO PRAXIS
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ABSTRACT

Educational paradigms and praxis are inherently dichotomous. This short paper offers an alternative conceptual viewpoint to help consider the idea of MSTE (Mathematics, Science and Technology Education) as a theoretical-practical dialogical confluence leading to idealised notions in paradigms and praxis. Through a process of theoretical reflective considerations, the central idea of an ethically and morally justified educational praxis is contemplated in the context of MSTE.

Introduction

Reformative thought in Mathematics, Science and Technology Education (MSTE) in the previously colonised African states has assumed an unprecedented level of urgency as reflected in the related discourse (Margaret, 2008). The resulting dialogical space the intelligentsia has created is thus preoccupied with a sense of despondence in the face of the socio-economic and political vestiges the continent has inherited. This is much to the discontent of those who fervently inaugurated a neoliberal educational dispensation, alien to the native proletariat’s conventional wisdom, which the successive post-colonial political institutions have unfortunately been burdened with (Anne, Malin, Sandra, & Claes, 2013). African academic thought is generally caught in between an intense urge to regain virtues lost to a long period of foreign intellectual incursions and the helplessness of the belittled ‘nativeness’ tethered to the very same subjugated past. The philosophical substratum of the notion of ‘education’, misused as an intellectual qualifier for discriminating citizens to decide upon whom ‘quality of life’ as an earned privilege must be bestowed, is therefore worth exploring. It is this existential dogma- emanating from the subversion of an institutionalised sanctity conventionally associated with education as an idea- in the context of pre-service teacher training in MSTE, that this research is trying to explore.

Drawing on the notions of professional development as conceptualised by Postholm (2012), this theoretical enquiry incorporates the essence of Vygotskian idea of situated learning philosophically reconstituted within the ubiquitous constructivist paradigm. An over-arching conceptual umbrella is however provided by tenets of critical theory and the Marxian notions of emancipatory pedagogies. The formulations are thus juxtaposed with the ideas of conventional as well as progressive ideological preferences that have characterised popular teacher education discourses of the 21st century (Brenda, Vivienne, & Susan, 2015).
From paradigms to praxis - the professional’s journey

The journey from paradigms to praxis, as undertaken by teacher educators of MSTE, through the exigencies of professionally attained fortitude, is riddled with contingencies such teachers are unprepared for. This uncertainty has its origin in the undisputed set of moral and ethical values teacher training as a socially committed exercise has traditionally been associated with (Andrew, David, & Joseph, 2014). Which ontological stand points have guided the formation of the idea of teacher training as a response to deprivation? Which moral code has underpinned the creation of the teacher as the instrument to serve a section of previously intellectually ostracised section of the society? The metamorphosis that every individual awaits, to unfold within the worlds of his/her thoughts, that leads such individuals to new intellectual awakenings is the answer to these questions (Laura, 2008). How the abstractions of that metamorphosis is epistemologically facilitated in the concreteness of practicality, as envisaged in the realm of teacher education, therefore deserves a worthy exploratory enterprise. A significant first step would be the re-constitution of the ideological tributaries that are fundamental to the notions of a morally just society. The making of such a society remains ingrained in the conceptualisation of educational praxis as a noble course teacher training should turn to (Tina, 2010).

The metaphor of tributaries mentioned above, in a philosophical sense, is collectively the core of teacher training as an ethically and morally correct social concept, very much in line with the notions of critical theory (Gloria & Robyn, 2007). The tributaries of morality, ethics and the associated praxis constitute the foundations of educational virtues. Creativity, for instance, as one such virtue is significant in the context of MSTE (Jennifer, Helen, & Derek, 2016). From paradigms to praxis, the teacher educator presides over the evolution of scientific, mathematical and technological frames of reference within which techniques, technicians and technologists are born to create. The revolution that unfolds in the classroom is thus a preamble to the technicist’s version of economic emancipation cognitively contrived and pedagogically reinforced. So what particular reconciliatory pedagogy should MSTE adopt? Reviving the relegated native discourses and revitalising the notion of principled praxis that define education as a virtuous experience, worthy of being lived, are perhaps answers to the question. A revisionist pedagogy that frees the soul from an intellectually subversive and insidious indoctrination perpetrated by the dominant utilitarian discourses is needed. Such a pedagogical discourse will shape a generation of mathematical, scientific and technological free thinkers (Ted, 2012).

Conclusion

In conclusion, within the confines of this short essay, the central argument is that a significant change in the arbitrary nature of adopted paradigms and the inherited reference points of morality, ethics and social justice are to be reconciled to achieve some degree of validity for educational
emancipatory thought to flourish in the context of MSTE. Praxis in MSTE thus becomes an entity well-grounded in the essence of such paradigms. The extent to which paradigms and praxis will continue to co-evolve is, however, for the critical theorists to ponder.

References


Introduction

The main objective of this paper is to challenge one of the main assumptions related to large scale assessment in Mozambique, by evaluating the systemic factors which may be related to the decrease in Grade 6 learner’s achievement in Mozambique between 2000, 2007 and 2014, looking for possible changes in Educational Effectiveness and pupil’s intake composition, over this period. It is secondary analysis of SACMEQ[1] data.

Globalisation of the economy and the relation between economic growth and education makes International Assessment Studies important for comparisons between and within countries with respect to educational outcomes (UNESCO, 2012). SACMEQ have been playing a major role in informing the education quality debate among policymakers and the general society in Mozambique.

Assumptions for large scale assessment studies in developing countries such as Mozambique are key issues that this paper discusses. According to Gustafsson (2010), the large-scale assessment studies are designed as longitudinal study at system level, but not at school level (e.g., PIRLS, PISA and TIMSS including SACMEQ), and the studies repeat every third, fourth or fifth year. The repetition is conducted in such a way that samples are drawn from the same population and the achievement tests are linked so that results are expressed on the same scales. This provides a basis for investigating trends in the levels of achievement for those countries that participate repeatedly, thus, this design is longitudinal at the level of school systems but not at the school or student level. Keeves (1988) refers to this kind of longitudinal research as a ‘trend design.’

The following questions could be raised about this “trend” assumption: (i) To what extent can the trend level of the achievement be measured where the pupil’s intake composition is changing over the time?

This research argues that in developing countries such as Mozambique, where access to education is still in progress pupil’s characteristics rather than school inputs and processes account for a large part of explained achievement variance. That is, when the education system is still not fully developed, evaluation of changes in school effectiveness, over time, is strongly associated with
changes in the pupil’s intake composition. The arguments are based in the analyse of data from SACMEQ II in 2000, SACMEQ III 2007 and SACMEQ VI in 2014.

To address the research questions this paper, evaluate the systemic factors which may be related to the changes in Grade 6 learner’s achievement in Mozambique between 2000, 2007 and 2014, looking for possible changes in Educational Effectiveness over that period. The specific research questions addressed are: (i) To what extent can the achievement decrease of six graders from 2000 to 2014 could be attributed to pupil’s intake composition changes? (ii)How much of pupil’s achievement is associated with changes in school inputs and processes, when student background changes between 2000, 2007 and 2014, is taken into account.

**Conceptual framework**

The conceptual framework underpinning the research is systems theory using an input-throughput-output. The systems theory of this research derives from the model of Shavelson, Macdonnell and Oakes (1987), with some elements added by Howie (2002). It represents the education system in terms of inputs, processes and outputs. The inputs are represented in terms of policy as well as antecedents, whilst policy refers to the education policies at national and local level that form the landmark of what pupils are supposed to learn, that is, the intended curricula. Antecedents are related to the allocation of human and material resources among regions and among schools within regions as well as the pupil’s background.

Processes are related to the extent to which schools provide learners with the opportunity to learn, that is a context conducive to learning and instruction. Therefore, processes that take place within the schools and inside the classroom influence what is taught and how it is taught. Outputs are related to learners’ achievement in the subjects and participation in class activities as well as their attitude toward learning and learner aspiration for the future (Howie, 2002).

Between inputs and processes, the model depicts school quality as a component that reflects how well school context environment is conducive to learning. School quality is influenced by inputs, as well as by quality of organisation and management of the resources at the disposal of the school.

As secondary data analysis, the research design was conditioned by that of the SACMEQ II and SACMEQ III, research design. The SACMEQ instruments include tests of Reading and mathematics, questionnaires for pupils, teachers and principals. The questionnaire design is guided by what is called ‘General Policy Concerns’ (Postlethwaite & Ross, 1992) summarised under the following themes:

- Pupil characteristics and their learning environments.
- Teacher characteristics and their views about teaching.
- School Head characteristics and their views about educational infrastructure, the organisation and operation of schools, and problems with pupils and staff.
- The reading and mathematics achievement levels of pupils and their teachers.

Sampling frame and sample

The target population of this study were Grade 6 learners attending the registered mainstream government or nongovernment schools in 2000, 2007 and 2014 in Mozambique. Taking into consideration that the study compared the results of SACMEQ II, III and IV, it was of paramount importance that the three samples were comparable. However, the comparability assumption could be put in question due to the sharp increase in the number of pupil and schools from 2000 to 20014.

For instance, the number of Grade 6 pupil has increased 144% from 2000 to 2007, and from 2007 to 2014 to rate of increase was 51%. Consequently, the number of schools has been also increasing, however, at higher rate when compared with pupils increasing rate, (around 200% from one point in time to the next; from 506 in 2000 to 1610 in 2007, to 5086 in 2014). Schools are getting closer to the pupil’s home.

The number of sampled schools was almost equal from 2000 to 2014. In 2000 the actual sample was 180 schools and 3118 pupils, in 2007 the sample comprised by 184 schools and 3660 pupils, whilst, in 2014, 2000 schools and 3360 pupils were sampled.

Statistical methods

The statistical analysis includes a descriptive analysis of outcomes, school inputs and processes. The descriptive analysis provides information related to the variables that have shown change, between 2000 and 2014 regarded as potential variables that may account for learners’ achievement variation across the time span. A hierarchical linear model approach was applied to model the factors that account for change in learner achievement level between over that period. That is, to investigate the extent of learner achievement variation, could be attributed to the changes in school conditions and teachers’ characteristics, while also controlling for the effect of changes in pupils’ intake composition.

Findings

This research argues that in developing countries such as Mozambique, where access to education is still in progress pupil’s characteristics rather than school inputs and processes account for a large part of explained achievement variance. Evidence suggests that from 2000 to 2007 considerable amount of pupil’s achievement decrease is accounted for variables such as parents’ education, whilst use of language of instruction, which could be an indicative of changes in pupil’s education, whilst use of language of instruction, which could be an indicative of changes in pupil’s intake composition between 2000 and 2007. Additionally, variance component analysis has shown that pupil’s reading achievement variance has increased sharply specially at school level. At school level the increase
between 2000 and 2007, was 43% and from 2007 to 2014 the increase 98%. It is easy to jump to the wrong conclusion here, which the education system has started to produce greater differences between pupils, when the differences were probably larger before children came to school. One can argue that the larger increase of school level variance, when compared to the increase in pupil’s level variance, could be attributed to rapid expansion of education access, that is, new schools are built in the areas in which learners are likely to have similar background.

For Wagner, (2012), who should be included in the assessment population and inequality in access to education is more than learning achievement. In this research, assessing those who do not speak the language of instruction at home is an indicator of inequality in education access rather than school producing greater differences between pupils. Assuming the longitudinal dimension of SACMEQ studies, in terms of the education system, the sample design assumption that the SACMEQ studies “therepetition is conducted in such a way that samples are drawn from the same population” is questionable. Therefore, the validity and the rational of the studies argued by Lockheed (2012) could be disputed.

[1] SACMEQ-Southern and Eastern Africa Consortium for Monitoring Education Quality- SACMEQ's mission is to monitor and evaluate the condition of schooling and the quality of education with technical assistance from UNESCO International Institute for Educational Planning (IIEP). The first major cross-national study, SACMEQI, was carried out 1995, involving in 12 countries with Mozambique only taking part in SACMEQII in 2000, SACMEQ III in 2007 and SACMEQ in 2014.
EXPLORING HOW INITIAL PRIMARY TEACHER EDUCATION PREPARES PRE-SERVICE TEACHERS TO TEACH EARLY YEARS MATHEMATICS

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ABSTRACT
This short paper reports on a proposed PhD study that seeks to explore how primary teacher education in Malawi prepares pre-service teachers to teach mathematics to beginning learners. Using Mathematical Discourse in Instruction (MDI) framework, the study focuses on understanding how pre-service teachers in teacher training colleges in Malawi are prepared to teach mathematics in early years, which include standards (grades) 1 to 4. Four Mathematics teacher educators and student teachers in teaching practice schools will be involved in the study. Data will be collected through lesson observations, semi-structured interviews, document analysis and focus group discussions.

BACKGROUND
Building a strong foundation in mathematics in the very early years of learners’ schooling is crucial for their success in mathematics in the upper classes. If teachers cannot develop learners’ mathematical inquisitiveness from the lower classes, there will be little chance of success in mathematics learning in the years that follow. Considering the significant role that mathematics plays in meeting the demands of everyday life, it is important that when learners are introduced to mathematics in their early years, they should find it meaningful, interesting and applicable to real life. However, this is not the experience that most learners have with mathematics. Most learners find mathematics to be a difficult subject that is abstract and has no meaning to their lives. This attitude learners have towards mathematics usually begins as early as primary school where, because of the way teachers handle the subject, learners fail to understand (Van de Walle, 2001). Most teachers present mathematical concepts in ways that make the learning of mathematics possible to only a few learners (Boaler, 2016); as a result, learners get frustrated, lose interest and rule themselves out of ever succeeding in mathematics.

This perception towards mathematics, followed by low achievement, is a matter of concern in Malawi, just as it is with many other countries. The education sector in Malawi is faced with many challenges, and one of these challenges is learner underperformance in Mathematics. There is growing evidence showing that many learners are performing poorly in mathematics in primary schools. Statistics from the Malawi National Examinations Board (MANEB) reveal that mathematics is one of the subjects in which learners perform poorly (MANEB reports, 2012, 2013, 2014). Results of the Primary Achievement Sample Survey (PASS) conducted by the Ministry of Education Science
and Technology (MoEST) to assess learner achievement in English and mathematics in standards three, five and seven revealed that less than 8% of standard three learners achieved the expected level of numeracy. No learner scored more than 50% in mathematics in standard five, and 99% of standard seven learners scored less than 50% in mathematics (MoEST, 2010). The Malawi Teacher Professional Development Support (MTPDS) assessment revealed that learners in primary school are performing at levels far below what the curriculum expects of them (MTPDS, 2010). Even at regional level, primary school learners have performed poorly on standardised tests for standard six learners done by the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ), with Malawi at numbers 13 out of 14, and 14 out of 15 in SACMEQ II and III respectively (SACMEQ, 2010). Learners continue to perform poorly in mathematics despite different interventions put in place by the ministry of education. This is worrying considering how important mathematics is for the development of the country.

While different factors can be attributed to the poor performance of learners in mathematics, such as shortage of teachers, increased learner enrolment, it is also important to look into how learners are introduced to mathematics in their early years by exploring how teacher education prepares pre-service teachers to teach mathematics in early years. Mathematics teachers in the early grades need effective instructional practices that involve learners in high-quality mathematics experiences. For mathematics teachers to develop these effective instructional practices, they themselves need to be mathematically skilled. These skills are introduced to teachers during their formal teacher education courses and continue to develop throughout their teaching service through CPDs. Shulman (1986) contends that pre-service teacher education is the principal source of teacher knowledge. This is where prospective teachers get the basics of teaching. The quality of training that they get determines, to a large extent, the quality of teachers they will make. Thus, it is important that pre-service teachers are given high quality mathematics education in order for them to effectively help learners develop a positive and appropriate image of mathematics from their early years of schooling.

It is in this regard that this study seeks to gain an understanding of how teacher education prepares primary school teachers to teach mathematics in early years, which include standards 1-4, with the assumption that to attain high learner performance in mathematics, teacher education should be of high quality. Looking at the existing literature, mathematics teaching and learning in the early years seems to be one of the areas that are under-researched in Malawi, and to the best of my knowledge, research is silent on preparation of pre-service teachers to handle mathematics in early years.

For analysis purposes, the study will examine the preparation of pre-service teachers for early mathematics teaching by focusing on number concepts and operations. Mastery of number concepts is the basis for competence in number and further success in other mathematical operations. Literature indicates that mastery of number concepts and operations in the early years play an important role in the development of mathematics achievement in the later years (Locuniak & Jordan, 2008; Jordan, Kaplan, Lamineni & Locuniak, 2009). Thus, because number concepts and operations are fundamental topic for learners’ understanding of other mathematical topics,
mathematics teacher education should stress the importance of it and help pre-service teachers in
developing effective ways of teaching before entering the mathematics classroom as teachers. The
study will specifically address the following questions:

1. What examples and tasks do mathematics teacher educators use when teaching the concept of
   number and operations to student teachers?
2. What explanations do teacher educators give when teaching the concept of number and
   operations to student teachers?
3. How do mathematics teacher educators involve student teachers in their lessons on early years
   mathematics?
4. How do student teachers use knowledge obtained from teacher training to teach mathematics
   during teaching practice?

THEORETICAL FRAMEWORK.

To answer these questions, the study will be guided by Adler & Ronda’s Mathematical Discourse in
Instruction (MDI) framework. Theoretically grounded in the sociocultural theories and empirically
grounded in mathematics teaching practices, MDI consists of the following elements: object of
learning, exemplification, explanatory talk and learner participation. Although I am aware that MDI
was developed specifically for secondary school mathematics, I decided to use it in teacher education
because it specifically targets mathematics teaching practices that are encouraged in teacher
education and can be used across a number of teaching and teacher education contexts.

METHODOLOGY

This study will use a qualitative case study approach in which four mathematics teacher educators
from one teacher training college will be observed teaching and then interviewed. Pre-service
teachers who will be practising their teaching in any four teaching practice schools belonging to the
participating teacher training college will be involved in focus group discussions. Document analysis
on mathematics schemes of work, lesson notes, lecturers’ and students’ handbooks will be done to
supplement information on where teacher educators get examples and tasks.
Piloting of the study will be done in October in one of the non-participating teacher training colleges.
Findings of the pilot study will be analysed and presented at the SAARMSTE 2019 for the purposes of
inviting comments on how I can improve the study.

REFERENCES


**ACKNOWLEDGEMENT**

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FORM, STRUCTURE AND REPRESENTATIONS OF ALGEBRAIC EXPRESSIONS: WHAT IS THE EXPLANATION?

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Abstract

The ability to interpret and connect multiple representations is an important and useful strategy which assists learners to understand the mathematics. However, representations, in their own right, have structure of which its understanding is essential before learners can gain fluency in working with and across multiple representations. The notion of multiple representations and structure are to a large extent research area that are often dealt with separately in the field while they both address a related and important educational concern. The goal of this paper is to examine the relation between the notions of form, structure and representations and how these together contribute to the explanation. By recruiting Ruben’s (1992) interpretation of Aristotle’s second criteria of explanation, which is form, I elaborate the notion of structure of algebraic expressions. I use document data from the larger study which was empirically located in a professional development project. The results reveal that form and structure are synonymously used and completely depend on the nature of the representation. I argue that there is a need to study the notions of form/structure and representations jointly rather than separately.

Form

The notion of form is borrowed from Ruben’s (1992) four criteria of explanation. Form is the second criterion of explanation. Form was defined as the arrangement or organisation of the elements which constitute the algebraic expression. The elements are the entities from which the structure is made. The form contains the qualities and character of the algebraic expression. When the form is taken apart, the parts or the element that constitute the form are the outcome. It is essential to understand the parts (elements) and the manner of putting them together in order to understand form. The notion of form is commonly referred to in the mathematics education literature as structure.

Structure

It is generally agreed that the notion of structure is an important aspect to understand in the teaching and learning of mathematics, specifically algebra (Sfard & Linchevski, 1994; Banerjee & Subramaniam, 2012; Rüede, 2013).

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8 The four criteria of explanation are matter, form, process and goal
Algebraic expressions take different structures according to their mathematical property. Hoch and Dreyfus (2010) cited in Rüede (2013) provide suggestions of general algebraic structures that are central to secondary education, namely: the difference of two squares: \( a^2 - b^2 \); the quadratic trinomial which can also be expressed as a product of two linear factors \( a^2 + 2ab + b^2 \); the expression where the multiplication of \( a \) is distributed into the addition of three unlike terms \( ab + ac + ad \); the linear equation: \( ax + b = 0 \) and the quadratic equation which can also be expressed as a product of two linear factors: \( ax^2 + bx + c = 0 \). Thus, structure is a mathematical property of the expression. The literature also emphasized actions such as recognizing, noticing and identification of structure. Rüede (2013) specifically argued that the identification of structure means recognition of individual terms that make up the expression. Banerjee and Subramaniam (2012) defined terms as units of the algebraic expression demarcated by the + or – sign, and they provide two types of terms. The first is what they call simple term and the second is a complex term. The definition they provide for a simple term is that it is a constant term, in this example \( 14 + 5x + 2(3x + 2) \) the constant term or simple term is 14. For a complex term there were two descriptions and that is a product term and a bracket term. In the example I provided \( 5x \) is an example of a product term because 5 and \( x \) are factors which make the product \( 5x \). In other cases of an algebraic expression \( x \) would be considered a product term because the two factors which are elements that make up the product term can be written as \( 1 \times x \). A complex term includes what they call the bracket term, for instance \( 2(3x + 2) \) in the example I provided is a bracket term.

Representations
The use of multiple representations has been advocated for as a useful strategy in the teaching and learning of school algebra (Wilkie, 2016; Zazkis, 2016). Research has emphasised the importance of using and moving between different representations when teaching mathematical concepts. The strategy of using different or multiple representations and making connections among them assists learners to better understand mathematical ideas. The representational systems used in mathematics allow for different types of structure to be experienced. The types of representations that are often reported and commonly used in literature concerned with school algebra are: written/spoken words; symbols; tabular representation; geometric representation; graphical representation. Representations, structure and form need to be studied together.

Methodology
The methodological approach that informed the larger study from which this paper comes from was qualitative. I collected documents data from the professional development (PD) project and then followed teachers into their classrooms. In this paper I use some of the document data from the PD. The PD offered a course to teachers called transition mathematics 1 (TM1). The TM1 course was constituted of mathematics focused sessions and teaching focused sessions. My interest was in the sessions concerned with teaching, and within these sessions I was particularly interested in the teaching sessions focused on explanation of algebraic expressions. The PowerPoint slide that I use in this paper was specifically taken from TM 1.8.
Results

The notion of the distributive property was used in TM 1 course. There are five aspects used which offer different types of explanation for the distributive law, these are: big idea, law, illustration, method, and short cut. The big idea and the geometric illustration were working as justifications for why the law works. I use the ideas of form, representations and structure, discussed earlier in this paper to look at the five aspects mentioned in the slide to exemplify the explanations of the distributive property.

![Figure 1 – Exemplification of explanation (taken from TM1.8 ppt slide 11)](image)

The forms/structures that were used for the distributive law were the product of two binomials – depicted as the method. The sum of four terms, three of which are product terms and the last is a constant term – depicted as FOIL short cut. The big idea is included as the reason behind the law ((x + 2)y + (x + 2)3). The rectangle was a form/structure used to illustrate the four terms (xy + 3x + 2y + 6).

The distributive property is represented using the symbolic and the geometric representation. Teachers were exposed to the ways in which they could teach the interpretation and connection between and among the two representations in order for their learners to make sense of the distributive law. The table below highlights and summarises this discussion.

<table>
<thead>
<tr>
<th>Table 1: Explanation of the distributive property</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distributive law</strong></td>
</tr>
<tr>
<td>Big idea</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Law</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Illustration</td>
</tr>
<tr>
<td>Method</td>
</tr>
<tr>
<td>Short cut FOIL</td>
</tr>
</tbody>
</table>

The FOIL method seems to be useful as a short cut to the law, however, it has its limitations because it is only applicable to the product of two binomials. Short cuts pose another limitation at the level of the explanation because they do not necessarily have a conceptual base which can be used as a justification for them. The geometric representation and its structure as well as the symbolically represented big idea and its structure are excellent approaches to teach the distributive law, because they are prior knowledge for a grade 9 learner. Furthermore, connections have to be made between the two representations. The application of the law will make sense once learners have understanding of the forms/structures of the two representations (geometric and symbolic).

**Conclusion**

The foregoing discussion has demonstrated that the notion of form/structure have the same explanation. I argue that once the notion of structure has been thoroughly understood, moving between, connecting and understanding multiple representations will be easier. The mathematics education community needs to be more committed to the teaching and researching of these ideas collectively rather than separately.

**References**


EXPLORING TEACHERS’ VIEWS ON TEACHING STRATEGIES THAT MAY ENHANCE PERFORMANCE IN A GEOMETRY CLASS

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Background context and purpose

Although the vision of South African education system promotes innovation and improvement programmes (DBE & DHET, 2013). There is still much that need to be addressed in order for this vision to be affirmed (Spaull, 2013). One of the aspects that need to be addressed is related to mathematics teaching and learning at school level. Studies have highlighted that performance in mathematics, especially geometry section is still a challenge at school level (Avalos, 2006; Dube, 2016; Mullis, Martin, Foy & Arora, 2012). How the section is taught is viewed as one of the contributing factors linked to this challenge (Department of Basic Education, 2014a). Within the South African context the challenge became more complex when geometry section in the FET Mathematics curriculum was withdrawn and categorised as a third paper and optional. The poor performance of the country in international initiatives such as TIMMS contributed to the challenge (Adler & Davis, 2006).

Theoretical framework

Different strategies have been proposed to effectively teach various learning areas (Star, et al., 2015). Emphasis of constructivism is on how to empower learners in taking responsibility learning experiences AMESA, 2010). Studies have shown that some of the specific skills and knowledge on aspects such as teaching strategies in geometry teaching, that is required during their training was found not to be adequate and relevant when they enter the world of work (Stols & Kriek, 2011).

Research question: What teaching strategies do you normally use in your Geometry lesson?

Methodology

Pragmatism is regarded as the philosophical underpinning that inform this paper. Pragmatic research is viewed as a research that focusses on finding solutions to specify problems by using qualitative and quantitative method approach (du Plooy-Cilliers, 2014). du Plooy-Cilliers, (2014) elaborates on pragmatism approach as “...commonly associated with mixed methods research [and it] offer an alternative worldview to those of positivism and constructivism [interpretism] and focuses on the problem to be researched and the consequences of the research”. Although, quantitative and qualitative data were analysed separately due to differences in the nature of data, the analysed data
was then integrated in order to address the themes or networks that were created, through Atlas TI programme and SPSS.

Results and discussions

Six themes emerged and analysed with Atlas.ti and SPSS are arranged as outlined below:

**Qualitative data**

In Question 4, teachers were required to provide information about their planning and preparation of day-to-day Geometry lessons. From the analysis, six themes emerged related to planning a lesson appropriately, depends on the content, prepare the lessons accordingly, done according to the schedule. use geometry as integration to the other mathematical content and re-teach things until most understand.

From theme 1 (Planning a lesson appropriately), teachers indicated that for effective teaching and learning to take place more effort should be put on planning their lessons appropriately that is weekly preparation of day to day. In this regards Ms Ledwaba said ‘My planning is on weekly basis and I include all support material in my planning’ (P1:234, 116:116). As elaborated by Borko, Koellner, Jacobs & Seago (2011), planning need to utilise other alternatives such as the use of video representations may be viewed support material in the planning. One element that comes up frequently in this theme is related to the importance and relevance of planning in a geometry class. Frequency of and what to include in the planning are essential if learners are to acquire a desirable knowledge and skills in geometry learning.

In theme 2 (depends on the content), teachers view planning a geometry lesson as including integration with other subjects, relating them to real life situation by allowing practical demonstration to take place in class (Moyer, 2001). Mr Molefe describe it in this way, ‘I plan geometry lesson for twice a week but during other days I used geometry as integration to other
content’ (P1:219, 100:100). In order for meaningful learning mathematics to occur, the use of everyday experiences is critical.

The items selected below represent teachers’ views on how he/she approach the teaching of geometry in a classroom situation.

**Quantitative Data**

Their teaching for learning is further shown on the above table where 63 (77.8%) of the teachers do their level best by trying to involve all the learners to actively participate in all geometry activities by also accommodating learners who seemed to be difficult in understanding. Hence only 18 (22.2%) teachers are not able to reach the few learners.

1. I know how to effectively help students use facilities such as calculators to solve mathematics problems. (27)

<table>
<thead>
<tr>
<th>MTQ_27</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strongly Disagree</td>
<td>1</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Disagree</td>
<td>10</td>
<td>12.3</td>
<td>12.3</td>
<td>13.6</td>
</tr>
<tr>
<td>Agree</td>
<td>44</td>
<td>54.3</td>
<td>54.3</td>
<td>67.9</td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>26</td>
<td>32.1</td>
<td>32.1</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

In their planning as well as presenting the geometry lesson to make it interesting and effective, teaching make use of other resources to help learners to understand or be actively involved70 in geometry activities. From the above table 70 (86.4%) teacher were in position to help students use facilities such as calculators to solve mathematics problems. Of which 13.6% of the teacher seems to be using traditional way of teaching of not involving learners or not using other resources.

2. In my Geometry classroom, I set up group activities where students learn a significant amount from each other. (30)

<table>
<thead>
<tr>
<th>MTQ_30</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disagree</td>
<td>3</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Agree</td>
<td>55</td>
<td>67.9</td>
<td>67.9</td>
<td>71.6</td>
</tr>
<tr>
<td>Strongly Agree</td>
<td>23</td>
<td>28.4</td>
<td>28.4</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>
Almost all teacher 78 (96.3) do involve students in group activities where all of them are actively involved teaching and learning. The main objectives is to teach for learning as well as seeing students being able to learn from each other to promote student-centred kind of learning.

3. Usually assign students activities so they can learn geometry on their own. (31)

<table>
<thead>
<tr>
<th>MTQ_31</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid</td>
<td>Disagree</td>
<td>3</td>
<td>3.7</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>Agree</td>
<td>58</td>
<td>71.6</td>
<td>75.3</td>
</tr>
<tr>
<td></td>
<td>Strongly Agree</td>
<td>20</td>
<td>24.7</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>81</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Teachers saw the importance of self-directed learning from the students. Quite a bigger number of teachers 78 (96.3) indicated that they usually assign geometry activities to their student as a way of encouraging them to work on their own that is known which encourages self-directed learning. This might encourage them to own their learning.

Recommendations

Findings from study may add new views on aspects to consider in teaching strategies for geometry teaching at school level. Furthermore, it may also add to the current strategies related to teaching and learning theories and practices in mathematics teaching and learning at school level, particularly in the context of the South African situation. Introduction of professional development programs to assist teachers in changing their teaching strategies during classroom practices that are frequently and unintentionally teacher-led and teacher-centred are needed.

Reference


Understanding Mathematical Thinking within Primary Preservice Teacher Education Programmes in South Africa
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Abstract
The importance of mathematical content and pedagogical content knowledge in the preparation of preservice teachers is widely accepted, but it is also imperative we draw attention to the importance of mathematical processes in the teaching and learning of mathematics. Unfortunately, many mathematics education students continue to experience mathematics as a rigid, formulaic manipulation of meaningless symbols which need to be reproduced, and do not develop the capacity to think mathematically. Mathematics teacher education has to address the low preparedness to students to teach mathematical thinking if school mathematics must be taught meaningfully. This paper discusses the development of a conceptual framework for mathematical thinking drawing from various literature and models related to processes of thinking and mathematics. The framework is used to inform the design of a questionnaire, for a small sample of university teacher educators in South Africa, to gain insight into their inclusion of mathematical thinking in course work. Our results indicate that teacher educators espouse the importance of mathematical thinking in their course objectives but experience difficulty identifying specific characteristics within their programmes. There appears to be limited time for deep engagement in mathematical thinking within courses and some characteristics are easier to include and assess while others are more tacit and require deeper inquiry.

Introduction

Although progress has been made towards the achievement of education for all, the quality of education remains poor for the majority of the world’s population. In mathematics education, Lovasz (2009) argues for the teaching of more general mathematical thinking competencies in addition to mathematics content to enable learners to contribute more meaningfully in a complex and changing world. Yet, even in well-resourced schools, the majority of learners do not engage with mathematics in a manner that is flexible, meaningful and precise. Rather, mathematics is learned as the rigid, formulaic manipulation of meaningless symbols. Many learners may be able to reproduce and apply symbolic forms, but often do not develop the capacity to think mathematically (Devlin, 2012; Katz, 2014). The same situation plays out in mathematics teacher education courses. The National Benchmark Test that first year students write at participating South African universities bear witness to low levels of content knowledge among education students, and even lower levels of mathematical reasoning skills. The Primary Teacher Education Project established work groups that attend to the enrichment of teacher education courses with regard to conceptual understanding and
reasoning in key mathematics content areas such as numeracy, algebraic reasoning and geometric reasoning. In addition to these working groups the mathematical thinking (MT) working group focuses explicitly on the development of mathematical thinking of mathematics education students. We present our analysis of the construct mathematical thinking through literature review, and then proceed to describe the empirical part of our research in this project.

**Literature review**

Enabling learners to develop experience of authentic mathematical activity is an active area of research in mathematics education and is acknowledged as the goal of authentic teaching. For some, the authentic teaching of mathematics involves the explicit “connection of mathematical concepts, skills, and strategies to purposeful, relevant, and meaningful contexts” to promote a deeper level of understanding of mathematics in the classroom (Keng & Kian, 2010: 305). We have selected from different approaches to teaching mathematical engagement to develop a conceptual framework which identifies specific characteristics that literature indicates as important aspects of mathematical thinking. Some examples are taken from literature which includes emphases on problem solving (Schoenfeld, 1992), mathematical reasoning, modelling, the strands of mathematical proficiency (Kilpatrick, Swafford & Findell, 2001), and participation in mathematical practice (Sfard, 1998). Rather than aim at defining mathematical thinking, this framework seeks to provide is a compilation of characteristics that is broad, provides for analytic precision and presents useful insight into the complexity of the process of mathematical thinking in action.

Elements of mathematical thinking were identified according to the following criteria:

- Each was a dynamic and active element of a person’s engagement in mathematics that could be related in a substantive way to cognition.
- Each element could be identified through a description of both the process of engagement, and the thinking involved.
- Element descriptions should be accessible to student teachers (who may have had a restricted prior experience of mathematical thinking)
- Individual elements may be distinguished through their process descriptions.

Thirteen process characteristics were identified for the conceptual framework, and clustered as follows:

1. Developing relational insight:
   - Developing insight using perception and action;
   - Identifying and exploring patterns and processes; and
   - Constructing and explicitly formulating connections.
2. Relating mathematics to the practical world:
   - Modelling and interpreting models; and
   - Identifying and relating properties that are quantifiable or measurable.
3. Formal structuring:
a. Forming and manipulating representations and formal tools;
b. Abstracting and generalizing; and
c. Describing and defining.

4. Deepening understanding and insight:
   a. Probing, exploring and hypothesizing; and
   b. Questioning, explaining and clarifying.

5. Reasoned argument:
   a. Justifying decisions, processes and conclusions (proving); and
   b. Investigating and explaining efficiency and effectiveness.

6. Showing perseverance and willingness to engage (fearlessness).

This paper reports on the preliminary analysis of the teacher educator questionnaires used to investigate the manner in which “mathematical thinking” is currently interpreted and taught in primary preservice education courses at a selection of universities in South Africa.

**Methodology**

This is a design research study and is part of a national Primary Teacher Education Project (PrimTed) which focuses on strengthening primary teacher education in mathematics. One of the Mathematical thinking working group aims is to design and research activities for grade 1–7 teacher education programmes, to extend preservice students’ experience of mathematical thinking. Academics from 10 different South African universities have volunteered to take part in this working group. The initial phase of the project involved the development of a conceptual framework based on the literature, as a guide for activity design and analysis. The second phase is a baseline study of how participating South African universities interpret mathematical thinking in the teaching of mathematics in their primary teacher education programmes. Participating lecturers completed a questionnaire with scaled responses (poor to excellent) as well as open response questions, based on the framework. They also provided us with examples from course materials and assessments. A qualitative analysis of the questionnaire data was carried out to produce a preliminary overview of the teaching of mathematical thinking at these universities.

**Findings and conclusion**

The results presented here are part of an initial analysis of the eight completed questionnaires received from six of the higher education institutions. They focus on the responses to questions 1 and 2 of the questionnaire which relate to course content and approaches to teaching as well as how effectively each of the mathematical thinking characteristics is included in the preservice teacher education programmes on a rating scale of poor to excellent. The results highlight three issues related to the teaching and learning of mathematical thinking within these teacher education courses. Firstly, while all course outlines include objectives related to critical thinking and problem solving, characteristics of mathematical thinking are seldom rated as achieved “reasonably well” or
“excellent” in the actual programmes. Secondly, is the open responses provide evidence of Mathematical Thinking topic coverage within courses but the time allocation to these deliberate mathematical thinking topics appears brief, fragmented and randomly ordered which could limit opportunity for the deep engagement required for the development of students’ mathematical thinking. Finally, it also appears that some characteristics, notably that of problem solving may be easier to formally include and assess, while other like exploring and conjecturing are more tacitly present and indicates a need for further research in terms of task design, teaching approaches and assessment.

This publication has been developed through the Teaching and Learning Development Capacity Improvement Programme which is being implemented through a partnership between the Department of Higher Education and Training and the European Union. The contents of this publication are the sole responsibility of Mathematical Thinking working group and should in no way be taken to reflect the views of the European Union.

References

Despite the numerous recent studies on tutor-student interactions in undergraduate courses with the aim of promoting students’ deep learning, little research has been done on the role of tutors in mathematical noticing during tutorials. This study therefore explores the role that tutors can play during mathematical noticing in an undergraduate Quantitative Literacy (QL) intervention course; more specifically, the undergraduate QL mathematics concept discussed in this study is the time value of money. Recent lines of research have, on the one hand, regarded higher education as a natural site for activities that promote students’ deep learning and critical engagements through robust and stimulating teaching and learning (Hardman, 2016; Herrmann, 2013). On the other hand, research has also shown that there is a lack of active participation by students during learning activities; according to Rocca (2010), one of the reasons for this is the poor quality of interactions between tutors and students.

Based on the research studies on noticing (Choy, 2013, 2015; Jacobs et al., 2010; Stockero, 2014), there is a dearth of research studies on the role of tutor noticing in higher education. Research studies involving the use of noticing in university mathematics classroom or reflecting on teaching are relatively few (Breen et al., 2014), and research that focuses on undergraduate teaching is scarce (Speer at al., 2010). Mathematics classrooms are complex settings where several interactions take place between teachers-students, and students-students. Sherin and Star (2011: 69) concurs and posit that “a teacher is bombarded with blooming, buzzing confusion of sensory data” during classroom complex settings. In these settings teachers need to decide in real time what they need to pay attention to, and need to interpret what they are attending to, finally they need to respond to the students’ understandings (Van Es, 2011). This study uses lesson study as a research methodology. Part of the argument of this study is that there should not be a difference between noticing as applied by teachers in schools versus noticing by tutors in higher education courses. Therefore, the aim of this study is to examine the roles of tutor noticing during the facilitation stage of a ‘research tutorial’. To be clear, the focus is not on the planning and reviewing stages of the research tutorial, but on the facilitation stage. Research tutorials are tutorials that are jointly planned by both tutors and researchers (Santagata, 2011, Teuscher et al., 2017). After planning, the tutor then facilitates the tutorial, while a research assistant acts as an observer. The final stage of the research tutorial occurs when tutors, the research assistant, and the researchers present their reflections on the students’ learning. Therefore, the three research questions that guided our enquiry are:
1. What do tutors notice during the facilitation stage of the research tutorial about students’ understanding of the concept of the time value of money?

2. What errors and misconceptions were noticed by tutors during the facilitation of the research tutorial, which were also observed in students’ written solutions in a test and an examination on the concept of the time value of money?

3. How significantly different were the students’ performances in the test compared to the examination on the concept of the time value of money?

The data for this study constitutes transcriptions of two tutorials, two tutor reflections on tutorials, and analyses of the students’ written work and scores from a test and an examination. The findings indicate that the major errors and misconceptions noticed by tutors during tutorial sessions remained unresolved by students, as evidenced by the students’ written solutions from a test and an examination – this could provide some guidelines for future professional development of tutors. In light of the findings, further research needs to focus on understanding the theoretical and practical connections between tutor mathematical noticing and the mathematical knowledge for teaching of the tutors.

REFERENCES


TEACHERS’ DISCOURSE PRACTICES IN MULTILINGUAL MATHEMATICS CLASSROOMS IN TWO NIGERIAN SECONDARY SCHOOLS
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This paper draws on the first Phase data analysis of my ongoing PhD research work that focuses on teachers’ Discourse practices in multilingual mathematics classroom in Nigeria. The main purpose of this study was to identify and understand what teachers’ Discourse practices were used in multilingual mathematics classrooms in northern Nigeria secondary schools. The study examines second-year senior secondary school (SS2) multilingual classrooms in one metropolitan township. At this particular township, because of migration, multilingualism in the mathematics classroom is obvious here more so than other areas.

An examination of current mathematics education research reveals that issues of teachers’ practices in the multilingual classrooms fall under a Discourse of school mathematics. My study is theoretically informed by Gee’s (2005) notion of Discourse. The discourse (with lower case d) otherwise called; language-in-use refers to how language is used “on site” (in the context) to enact practices (Gee, 2005, p. 1). When discourse (language-in-use) is combined integrally with non-linguistic symbols to enact specific practices then, Discourse (with uppercase D) is involved. This study adopts the notion of Discourse (with uppercase D). Discourse analysis theory (Gee, 2005, p. 6), “seeks to balance talk about the mind, talk about social interaction and activities, and talk about society and institutions”. Practice in this study refers to the use of spoken/written language and non-linguistic symbols by one or shared by two or more people to “make clear to others what it is [they] take to be doing” (Gee, 2005, p. 11). Gee looks at language-in-use together with non-linguistic symbols, objects of thinking, and feelings. Gee (2005) contends that the key to understanding Discourse is recognition. Recognition work is the way people (teacher/students in this instance) engage in certain work to make visible to others (and to themselves) who they are and what they are doing. The study’s research questions were: What Discourse practices are used by teachers in northern Nigerian multilingual mathematics classrooms? How do teachers enact practices, during Discourses in teaching and learning in multilingual mathematics classrooms of northern Nigerian? Why do teachers use particular Discourse practices in multilingual mathematics classrooms in northern Nigerian?

Mathematics teaching in a multilingual context has been the subject of interest to many researchers (Adler, 2001; Barwell, 2004, 2009; Clarkson, 2005; Essien, 2010; Howie, 2003; Moschkovich, 2009). All these studies have argued for continuous attention to the teaching of mathematics in multilingual classrooms. One of the objectives of all mathematics teachers is for students to learn the Discourse of mathematics, which includes symbols, words, phrases, mathematical notations, and the ability to
write and talk mathematically (Adler, 2001; Barwell, 2004; Moschkovich, 2002, 2003; Setati, 2002). A focus on Discourses together with multilingualism in the mathematics classrooms in Nigeria has implication for how teachers/students enact practices during their lessons (Federal Ministry of Education (FME, 2012)).

Focusing on Nigeria, Okunrinmeta (2014) shows that students preferred to learn mathematics in English along with their home languages instead of English only, as they can express themselves better using both languages. In the Nigerian context, there seems to be limited literature on the detailed descriptions and analysis of the language issues in the multilingual mathematics classroom. Of the one hundred and twenty-three articles published in ABACUS, the leading journal in mathematics education in Nigeria and the journals of mathematics education panel, published by the science teachers association of Nigeria from 2005 to 2014, only three articles focused on language issues in a multilingual mathematics classroom. The notion of Brantlinger, Jimenez, Klingner, Pugach, and Richardson (2005) was used as a guide to the qualitative research methodology for this study.

According to Brantlinger et al (2005), qualitative research is “a systematic approach to understanding qualities or the essential nature of a phenomenon within a particular context” (p.195). Therefore, with the qualitative method, it was insightful to gain detailed descriptions of the experiences of my participants on the language and other interactions in multilingual mathematics classrooms. The population of the study was multilingual mathematics teachers of two secondary schools located in one of the metropolis in northern Nigeria. The sample was four purposively selected multilingual mathematics teachers from secondary schools. Data gathering techniques for this study included video observations, written field notes and face-to-face interviews in schools and classrooms. The preliminary finding from the data analysis of the first Phase of this study shows the following most privileged Discourse practices: reiterating, proceduralising, explaining, re-voicing, Code-switching/translating, questioning and regulating.

REFERENCES


EXPLORING IN-SERVICE MATHEMATICS TEACHERS’ LIVED EXPERIENCES OF PROFESSIONAL DEVELOPMENT

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Abstract

In this paper we report initial results from an ongoing phenomenological study that seeks to understand the meanings teachers attach to their participation in professional development. In the full paper that we will present at the SAARMSTE conference, we will present results from teachers’ reflections on their PD experiences. The goal of the PD was to deepen teachers’ mathematical knowledge for teaching. Thirty-three mathematics teachers were requested to write down reports about their participation in the PD. Data analysis was conducted with theoretical tools drawn from phenomenology. Results suggest that teacher participation in the PD may be associated with growth in teachers’ understanding of selected school mathematics content and change in their perception of good teaching.

Introduction

Professional development (PD) is critical for improving teachers’ capacity to provide the teaching quality we so much desire for our children. Research has shown that teaching quality is related to learner achievement (Fishman, Marx, Best, & Tal, 2003; Harris & Sass, 2011). There is a tendency for teacher professional developers to assume that teachers have learnt what was made possible to learn in the PD. However, drawing from Variation theorists (e.g. Ling Lo, 2012), and the duality of the object of learning in mathematics teacher education (Adler & Davis, 2006) provision of PD does not necessarily lead to teachers learning what was desired. This is because the enacted and the lived object of learning do not always cohere particularly when object of learning is dual (i.e. both mathematics and teaching) in teacher learning. Moreover, if teachers do learn, there is no guarantee that the new innovations will become part of the teacher’s pedagogical repertoire in the classroom. Thus, it is imperative that any PD is subjected to some evaluation to explore whether its goal of developing teachers has been realized. It is also critical to understand whether the PD was beneficial to participants. Thus, in this paper we sought to explore the teacher’s experiencing of the PD. The particular question of interest was posed as follows: What does it mean to experience content focused professional development? As we were concerned with the teachers’ experiences, we drew our theoretical resources from Husserl’s descriptive phenomenology which has more productive tools in handling questions about experiences and meaning making (Creswell, 1994; Giorgi, Giorgi, & Morley, 2017). We worked with the notions of intentionality of conscience, horizontalization, meaning...
structure and essential meaning structure (Broomé, 2011; Creswell, 1994). The notion of intentionality of conscience proposes that what our talk foregrounds is the focus of our minds and so is true for us at the time when it is in focus. This notion helped us to trust and believe teachers’ reflections. Horizontalization refers to disaggregation of the original data into analyzable pieces. The meaning structure refers to the pieces of data which may be put together to form themes. The essential meaning structure is the sum of all emergent themes and it is what it means to experience some phenomenon (Creswell, 1994; Gallagher & Francesconi, 2012).

Methods

The study followed a descriptive qualitative research approach in both data collection and analysis. The participants were 33 mathematics teachers who have participated in one PD program between 2016 and 2017. Data for the study was captured through teachers’ written reports. The reports were collected at the end of their participation. As mentioned above, a descriptive phenomenological analysis was conducted to capture the meanings teachers attached to their involvement in the PD. The analysis was guided by ideas already articulated above.

Results

Table 1 and Table 2 contain three columns. The first column shows script numbers. These are used to identify scripts with particular data that produced the meaning structures. The scripts were numbered from 1 to 33 for ethical considerations. However, numbering scripts in this way aided our data analysis. The second column contains meaning structures that emerged after pulling together pieces of data from different sources containing similar meanings. Outside phenomenological research these might constitute sub-themes. The third column contains the themes. In the discussion section below the themes are drawn together to describe the essential meaning structure to answer the research question.

Table 1 shows that there were 13 scripts from which 7 meaning structures were developed and that together the meaning structures produced one theme. What is common about the meaning structures is their essence. Each of the seven points informs that something happened to teachers’ knowledge of mathematics in the TM1 course. Now, in Table 1, any reference to teachers’ own mathematics per se appears in bold and that which has happened to this mathematics is underlined. Reference to mathematics is evident in words that include: knowledge of functions; confidence (in mathematics); knowledge of trigonometry; algebra and functions; and mathematical knowledge. In each meaning structure teachers suggest that something positive happened to their mathematical knowledge. This is evident in the use of words that include: improved; clarified; understand; and rejuvenated.
Table 1: Teachers’ experiencing of PD in relation to mathematics per se

<table>
<thead>
<tr>
<th>Script numbers</th>
<th>Meaning structures</th>
<th>Themes</th>
</tr>
</thead>
<tbody>
<tr>
<td>5; 6; 7; 12; 13; 16; 17; 22; 23; 25; 29; 32; 33;</td>
<td><strong>My knowledge of functions</strong> has improved</td>
<td>Growth in teachers’ understanding of mathematics per se</td>
</tr>
<tr>
<td>5; 6; 7; 12; 13; 16; 17; 22; 23; 25; 29; 32; 33;</td>
<td><strong>Difficult topics</strong> were clarified</td>
<td></td>
</tr>
<tr>
<td>5; 6; 7; 12; 13; 16; 17; 22; 23; 25; 29; 32; 33;</td>
<td>My confidence has improved</td>
<td></td>
</tr>
<tr>
<td>5; 6; 7; 12; 13; 16; 17; 22; 23; 25; 29; 32; 33;</td>
<td><strong>My knowledge of trigonometry</strong> has improved</td>
<td></td>
</tr>
<tr>
<td>5; 6; 7; 12; 13; 16; 17; 22; 23; 25; 29; 32; 33;</td>
<td>I understand the link between <strong>algebra and functions</strong></td>
<td></td>
</tr>
<tr>
<td>5; 6; 7; 12; 13; 16; 17; 22; 23; 25; 29; 32; 33;</td>
<td>I have developed understanding of <strong>mathematics</strong></td>
<td></td>
</tr>
<tr>
<td>5; 6; 7; 12; 13; 16; 17; 22; 23; 25; 29; 32; 33;</td>
<td><strong>My mathematics knowledge</strong> is rejuvenated</td>
<td></td>
</tr>
</tbody>
</table>

Similarly, Table 2 above has the same three columns as Table 1. The difference between the two is what is foregrounded in the meaning structures. It can be noticed through underlined and bold words that teachers are saying something positive about their teaching per se. Words used include: teaching; my learners; selection of examples; justification in a lesson; mathematical language; and taught mathematics. The use of words such as confident; deepened and extended; more careful and patient; and improved, suggest that something positive happened to the teachers’ capacity to teach.

Table 2: Teachers’ experiencing of TM1 in relation to teaching mathematics

<table>
<thead>
<tr>
<th>Script numbers</th>
<th>Meaning structures</th>
<th>Themes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1; 2; 3; 4; 5; 7; 8; 9; 10; 11; 12; 13; 14; 17; 19; 20; 21; 23; 25; 27; 28; 29; 30; 32; 33</td>
<td>I am more confident in my <strong>teaching</strong>. The course has deepened and extended my <strong>teaching</strong>. I am now more careful and patient <strong>with my learners</strong>. My <strong>selection of examples</strong> has improved. I understand that <strong>justification</strong> is important in a <strong>lesson</strong>. My use of mathematical language has improved. I taught mathematics without understanding before. Now my knowledge has grown</td>
<td>Change in teachers’ perceptions of their ability to teach mathematics</td>
</tr>
</tbody>
</table>

232
Conclusion

Returning to the question of interest: What does it mean to experience content focused PD: Bringing the two themes together to constitute the essential meaning structure of teachers’ participation we may assert that participation in the PD enhanced teachers’ sensitivities about their knowledge of mathematics and this is evidenced by increased confidence; improved understanding of school mathematics, and rejuvenation of their mathematics. Participation also facilitates change in teachers’ perception of what is needed to improve teaching quality in the classroom. Knowledge of mathematics is critical for improved teaching quality and the two have strong associations with improved learner achievement. It appears what was intended is experienced. Questions of course remain as to what these are in more detail, particularly in the orientation to mathematics, and key teaching practices and their enactments.

Acknowledgment

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References


THE APPLICATION OF THE ASPECTS OF UNIVERSAL DESIGN FOR LEARNING TO ENHANCE THE TEACHING OF WORD PROBLEMS IN A MULTILINGUAL MATHEMATICS CLASSROOM

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Mathematics Word Problems are the mathematical exercises of which the content is offered in a story form (Kasule & Mapolelo, 2013). The word problems have proven to be the most challenging problems learners have to solve in Mathematics Education (Bernado, 1999). This mathematical genre demands a lot from the learners in order for the problems to be successfully solved. For instance, in order for the learners to solve these problems, they need to have the capacity to reason with numbers, identify, understand, interpret, create, communicate and compute numbers (UNESCO, 2004). Over and above this, the learners need to be proficient in English, be able to read, understand the mathematical vocabulary and register and be able to visualise the problems amongst others, which is what they are unable to do in most instances (Moleko, 2018). Literature indicates that mathematics word problems are not only a “nightmare” to the learners but also to the teachers. According to Pearce, Bruun, Skinner and Lopez-Mohler, (2013) and Seifi, Haghverdi and Azizmohamadi (2012) teachers also find the word problems challenging to solve and this poses serious challenges for them to teach it effectively. Essien (2013) notes that it is even more challenging to teach this type of mathematics in multilingual classrooms where multiple languages are spoken and the language of learning and teaching (LoLT) is not the first language of the learners or the teachers. According to Barwell (2009), the challenge of teaching in such classrooms is that learners are not yet proficient in the LoLT and therefore this requires the teachers to pay attention to mathematics itself, English as a LoLT and mathematical language and to strike a balance thereof. According to Moleko (2018) most teachers find it difficult to strike this balance and support the learners since they, themselves at times struggle with the LoLT. In addition, Essien (2013) emphasises the need for the teachers to be trained in order to teach word problems effectively in multilingual mathematics classrooms. On the basis of all this, the purpose of this study was to highlight some of the aspects of universal design for learning (UDL) which were utilised to facilitate the teaching of word problems in a multilingual mathematics classroom.

UDL is an educational framework that guides the development of flexible learning environments that accommodate individual learning variances. It is underpinned by the following principles: multiple means of representations, action, expression and engagement (Courey, Tappe, Siker & Lapage, 2012). Through the application of the UDL principles, teachers can accommodate learners and enable them to engage with content in various ways, and also cater for the learners who speak English at varied levels of proficiency (Webb & Hoover, 2015). Furthermore, the application of UDL enables the teachers
to present content in multiple formats and thus make it accessible and applicable to learners with
diverse backgrounds, learning styles, and abilities (Oman, 2012). UDL has proven to be the best
strategy to provide teachers with a variety of options in terms of teaching and catering for the needs
of the learners in class (Ndeya-Ndereya, 2016). Even though UDL proves to be a good strategy that
promotes inclusivity in teaching and learning, most teachers seem to be teaching word problems
unproductively and in ways which do not promote inclusivity for all the learners and thus limiting
learners’ understanding of the mathematical concepts embedded in the word problems.

The study was informed by the following two key questions:

• What are the challenges pertaining to the teaching of word problems in a multilingual
  mathematics classroom?
• What kind of UDL teaching strategies can be employed to teach word problems in a multilingual
  mathematics classroom?

This was a qualitative study which was carried out in a form of participatory action research (PAR),
drawn from a larger study (Moleko, 2018). The study was underpinned by critical emancipatory
research (CER) as a theoretical framework guiding it. The selection of this lens was informed by its
transformatory and empowering nature (Tlali, 2013). Data were analysed through the use of critical
discourse analysis (CDA) which made it possible for such data to be analysed at textual and social
analysis levels and to also highlight the discursive practices (van Dijk, 1999). The study was conducted
in one of the schools from the Thabo-mofutsanyane district. The school was selected because of the
availability and the willingness of the teachers and learners taking part in the study. The teachers
were also aware of the challenges pertaining to the teaching of mathematics in a multilingual setting.
Furthermore, the school comprised of the learners from various linguistic backgrounds. The school
also had many learners who came from different backgrounds and who spoke different languages
even though the use of English was encouraged above the use of other official languages.

In providing answers to the guiding research questions for this study, I firstly reviewed the literature
relevant to the teaching of word problems and also the teaching of mathematics in multilingual
mathematics classrooms. This enabled me to understand the challenges that are presented by the
teaching of this mathematical genre in a multilingual setup. The strategies that could effectively assist
the teachers to teach word problems effectively were therefore derived from the literature and the
empirical data. A number of lessons and teaching strategies emerged from the study namely, the
provision of sufficient teacher training for effective teaching in multilingual mathematics classrooms,
the use of effective instructional strategies such as code switching, visual techniques (e.g. diagrams),
teaching of mathematical vocabulary and register as well as providing materials and instruction in
the home language where possible.
Keywords: Universal Design for Learning, Universal Design, Mathematics, Word Problems, Multilingualism, Multilingual Mathematics Classroom, Critical emancipatory Research, Critical discourse Analysis, Application, Flexibility

References

ADAPTATION OF MATHEMATICS TEXTBOOK TO DAILY SITUATIONS OF STUDENTS IN MOZAMBIQUE: CASE OF 8TH CLASS

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The textbook is one of the most important resources for teaching - learning mathematics. For this reason, a number of studies have examined the use of mathematics textbooks by teachers. This study examines the extent to which teachers adapt textbooks suggested exercises to real life application. That is because the mathematics teaching program in Mozambique suggests that teaching - learning in mathematics should equip students with the basic skills needed to solve problems and explore situations based on experiences of everyday life. The present empirical investigation results from analysis of the adequacy between the program contents, textbook exercises and students' daily problems. The literature review focuses on the teaching of mathematics program of 8th grade, in relation to the proposed methodology and the consistency with the exercises presented in the textbook. In order to raise questions related to the daily exercises of the students, this study evaluates the exercises in relation to their usefulness in solving the problems of the day to day. Then, the results of the study are outlined in this article focusing on the common and divergent points between the teaching program and the contents presented in the textbook of 8th grade mathematics teaching in Mozambique. The analysis has shown opportunity for teachers to use mathematic games in order to bring the contents into students’ real life.

References

TENSIONS IN TAKE-UP FROM OF A PROFESSIONAL DEVELOPMENT PROGRAMME: The Case of One Secondary Mathematics Teacher
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Abstract
This is a case study of one mathematics teacher’s take-up from a professional development course and the tensions faced by the teacher in implementing aspects of the course in his classroom. It is part of a larger study investigating the affordances provided to learners in their learning of mathematics by carefully constructed examples and teacher explanations in a secondary mathematics classroom.

Introduction
Teachers in the Transition Mathematics (TM1) professional development course are introduced to a mathematics teaching framework (MTF) (Adler & Ronda, 2015), to use as a guide when planning and executing lessons. A focus in TM1 is how to make clear the object of learning (OoL) i.e. what learners need to be able to know and do by the end of a particular lesson and how the careful choice of examples assists in attaining the OoL. Also, in focus is how teachers move between mathematical and non-mathematical language to explain concepts and justify procedures i.e. their explanations. Furthermore, the emphasis in the MTF is how both the construction of an appropriate example set as well as the explanations by the teacher aid in generalisation of the concept/s being taught. I explore how teachers who have attended TM1 take up the above components of the MTF in their practice of teaching mathematics with a focus on the relationship between their practice and TM1 in their complex and varied school contexts. To do this, I focus on their teaching of two different topics, one of which they had covered in the course (quadratic equations) and one that they did not (number patterns).

Literature review
Some professional development programmes report little improvement on teaching practices (Garet et al., 2011; Harris & Sass, 2011) while others indicate some improvement on teachers’ classroom instruction (Desimone, 2011; Pournara, Hodgen, Adler, & Pillay, 2015). However, Clarke (1994) reports on delays on the effects of teacher development courses due to various factors. Some of the impediments to teacher’s implementations of aspects of professional development programmes are lack of time for planning and reflection by teachers and perceptions of learners, parents and principals about effective content and pedagogy. Westaway and Graven (2018) refer to these impediments as tensions which may arise, for example, from curriculum and teacher beliefs that
enable or constrain teachers in their teaching of mathematics. Tatar (2007) describe tensions as a result of the difference between “what is and what ought to be”.

**Methodology**

In the wider study I focus on four teachers and how they choose and explain examples to illuminate the concepts being taught. During 2018 I observed and video recorded lessons of the teachers on the two different topics. Teachers were provided with videos of excerpts of their lessons to look at before a video stimulated recall interview (VSRI) was conducted. The entire data collection process will be repeated in 2019 with the same topics taught by the same teachers to enable me to examine whether and how teachers have changed the ways in which they select examples and provide explanations. This is especially relevant in light of literature on delays on the effects of professional development.

Analysis of data will be accomplished using the Mathematics Discourse in Instruction (MDI) which is an analytical tool used to describe how the MTF is operationalised in the classroom (Adler & Ronda, 2015). The explanation component of the tool centres around what is written by the teacher on the board (haphazard, precise, full procedure), what is said by the teacher (use of mathematical and non-mathematical words) and how the mathematics is justified (to promote the generalization of the concept/s in focus in a lesson).

**The case of Tsebo**

I focus on one teacher’s (Tsebo) teaching of a Grade 10 lesson on number patterns (that was not covered in TM1) and the tensions he faces in the take-up of the MTF as revealed by the VSRI. I focus on the introductory lesson. Excerpts of videos were provided to Tsebo before the VSRI. While the videos focused on particular parts of the lessons, the purpose of the VSRI was not only to probe his thinking when selecting particular examples or providing explanations but also as a springboard to discuss his take-up of the MTF as a whole.

Tsebo commenced the lesson by defining the words “constant difference” and “consecutive”. He then asked learners to find the 701st term of an arithmetic sequence. He said he chose this example so that learners would be forced to consider other options of finding the term to avoid listing 700 terms. This provided the justification (which is one of the focal points of the MTF) for introducing a formula for the general term of an arithmetic sequence which, he declared, learners could now use to find any term number.

Tsebo defined the word consecutive as “They follow each other .... So, can you see that the difference is the same all the time?” Tsebo’s definition of “consecutive” appears to be closely attached to a common difference and therefore only to arithmetic sequences. This is further reinforced in his lesson when he mentioned, “Can you see 14 minus 7 what do I get? Twenty-one minus 14?” When asked how learners would generalise “consecutive” in a sequence like 1; 4; 9; 16; ... Tsebo conceded
that he didn’t think learners would think of 1; 4; 9 as being three consecutive numbers because he seemed to have been re-inforcing the word consecutive to be “pairs of numbers”. In this instance the VSRI served to assist the teacher in reflecting on his explanations in his teaching of the lesson.

Tensions
I use the word tensions as factors impeding Tsebo’s take-up of the MTF in his classroom teaching practice and so briefly summarise some of these factors. In his lesson on number patterns, Tsebo just provided the formula for the general term of an arithmetic sequence without deriving it in the form $y = ax + q$ as demonstrated in the text book. This formula $Tn = ax + q$ can be derived using the common difference. During the interview, he stated that deriving it in the way used in textbook confuses learners as happened in the past. Furthermore, he also mentioned that because of their confusion, they asked too many questions which took up a lot of time. He would rather provide them with the formula and show them how it was derived if he had the time. Finally, he also indicated that in the exams or in tests, “this is the one (referring to the formula $Tn = a + (n - 1)d$) they actually need”.

Three key findings from the interviews indicate the tensions faced by Tsebo in take-up of the MTF.
• Learner performance in exams was the key driving force in his choice of examples and explanations in his lessons on both topics
• Learners resisted when he previously demonstrated how to derive the formula to find the general term of an arithmetic sequence or why a certain procedure works.
• Tsebo explained that he would discuss why a particular procedure works or how the formula was derived if he had the time to do so.

Conclusion
While Tsebo provided a justification for the use of a formula to find the general term of an arithmetic sequence, he elected not to show why the formula he chose was a more suitable one than the others (e.g. $Tn = ax + q$) to accomplish this. Tsebo’s take-up of the framework was limited by various factors as shown above. Tsebo’s lesson on quadratic equations (which is not reported here and was covered in TM1) did show some form of take-up of the MTF. A question that needs to be pursued further is “Was it because the topic “number patterns” was not covered in TM1 that he was not willing to risk learners being confused by deriving the formula?”

References


The Paper reports on the results of the Primary Teacher Education Project mathematics assessment that was administered to the first-year students. The assessment was administered to 232 students. The results show that the average performance of the students was 55.26%. In terms of mathematical content, the students performed the highest in Geometry with the average of 66.38% and the lowest performing category was Algebra with an average mark of 46.93%.
RELATIVE DIFFICULTY OF ADDITIVE RELATION WORD PROBLEMS IN ISIXHOSA
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Abstract
While additive relation word problems and their relative difficulties have been studied in detail in English, much less research has attended to word problems in other languages. This paper sets out to provide a better understanding of word problems and their relative difficulties in isiXhosa, one of South Africa’s official languages. This will be done by analysing the results from an early grade mathematics assessment administered to 360 Grade 1-3 isiXhosa learners in 6 rural Eastern Cape schools. In particular, this study will compare the relative difficulty of English word problems with those of isiXhosa word problems.

Introduction
Additive relation word problems and the relative difficulty of different types of word problems have been studied in detail in relation to English (e.g. Riley, Greeno and Heller, 1984). Such studies have shown that there are a number of factors that influence the difficulty level of different word problems such as the semantic structure and the position of the unknown (Riley, Greeno and Heller, 1984). Word problems form an important part of the early grade curriculum in South Africa. However, they have been identified as a recurring weakness in the South African Annual National Assessments (ANAs) (Department of Basic Education, 2012, 2014, 2015). They therefore warrant further research. In particular, studies demonstrating that some types of word problems are easier to solve than others point to the value of introducing different types of word problems in different grades, rather than introducing all types in Grade 1 as is currently specified in the curriculum and assessment policy standards (CAPS) document (Department of Basic Education, 2011).

Literature review
Researchers that have compared the relative difficulty of word problems have categorised word problems using similar typologies (e.g. Carpenter and Moser, 1983; Riley, Greeno and Heller, 1984). These typologies have been combined into a comprehensive typology of 11 types of word problems, each with two subcategories resulting in 22 problem types, by Author (in press). The labels from this comprehensive typology will be used in this paper.
Research on the relative difficulty of word problems has consistently shown that compare type problems are the most difficult to solve while change type problems are the easiest (e.g. Nesher, Greeno and Riley, 1982). Such research has also demonstrated that problems where the sets that are being acted on are unknown (e.g. change problems where the start unknown or collection problems where the subset is unknown) are more difficult for learners to solve than problems where the resultant set (e.g. the result in change problems or the collection in collection problems) is unknown (Riley, Greeno and Heller, 1984).

Research has also shown that rewording a problem can make it easier for learners to solve. For collection problems such as ‘There are 6 children on the playground. 4 are boys. How many are girls?’, including the phrase ‘the rest are girls’ increases the likelihood that learners will be able to solve the problem (Riley, Greeno and Heller, 1984).

For compare type problems, two variations have been shown to make problems easier to solve. The first, proposed by Hudson (1980), involves asking learners to match two sets (e.g. children and oranges) and to determine ‘who won’t get’ (rather than asking how many more are in one set than the other). A stricter version of this variation is described by Roberts (in press) and involves contexts that require one-to-one matching (e.g. pots and lids or locks and keys) and asking learners to determine how many are missing from the smaller set. Both these variations are included in this study in order to determine whether such rephrasing changes the difficulty level of word problems in isiXhosa as well as in English.

### Research questions and methodology

This study aims to address the following questions:

1. What are the relative difficulties of additive relation word problems as administered to and solved by isiXhosa Grade 1-3 learners?

<table>
<thead>
<tr>
<th>Dynamic (like a movie)</th>
<th>Static (like a photo)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single set</strong></td>
<td><strong>Collection</strong></td>
</tr>
<tr>
<td>Change</td>
<td>subset + subset = collection</td>
</tr>
<tr>
<td><em>start ± change = result</em></td>
<td><em>Collection unknown</em></td>
</tr>
<tr>
<td><em>Result unknown</em></td>
<td><em>Subset unknown</em></td>
</tr>
<tr>
<td><em>Change unknown</em></td>
<td><em>Start unknown</em></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Separate sets</strong></th>
<th><strong>Compare</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Equalise</td>
<td>referent ± difference = compared quantity</td>
</tr>
<tr>
<td><em>start ± change = target</em></td>
<td><em>Target unknown</em></td>
</tr>
<tr>
<td><em>Change unknown</em></td>
<td><em>Difference unknown</em></td>
</tr>
<tr>
<td><em>Start unknown</em></td>
<td><em>Referent unknown</em></td>
</tr>
</tbody>
</table>
2. Do the relative difficulties of word problems, when posed in isiXhosa to isiXhosa home language speakers, correspond to the relative difficulties of word problems when posed in English to English home language speakers?

3. If relative difficulties differ in English and isiXhosa, what might account for these differences?

In order to answer these questions, results from an Early Grade Mathematics Assessment (EGMA) will be analysed. The EGMA included six-word problems, four of which were additive relation word problems. An additional two compare type word problems were included in order to establish whether, like in English, rephrasing compare type problems increases the ease with which learners solve these more difficult problems. There were thus a total of six additive relation word problems in the assessment (two change problems, one collection problem and three compare problems, see Appendix A). The six problems were translated into isiXhosa by an accredited translator. The assessment was administered by isiXhosa speaking adults to 360 Grade 1-3 learners individually, in 6 rural Eastern Cape schools. Each question was read to the learner, first using isiXhosa number names, and then using English number names. Results (correct or incorrect) were recorded on tablets and then extracted into a spreadsheet for analysis.

The way forward

The assessment has been administered and the results have been collated. The next step is to analyse the results and to rank the word problems in order of easiest (solved correctly by the highest percentage of learners) to most difficult (solved by lowest percentage of learners). These results will also be disaggregated by grade, and, potentially, by age, school and whether the learner attended Grade R or not. The ranking of the different types of word problems will then be compared with those of other studies and possible reasons for differences (if any) will be discussed.

References


Hudson, T. (1980) Young children’s difficulty with ‘How many more than are there?’ questions. Indiana University.


**Appendix A: Word problems**

<table>
<thead>
<tr>
<th>Change (increase)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Result unknown</strong></td>
<td>Kukho abantu abathathu emotweni. Kuze kungene abanye abane. Bangaphi bebonke abantu abasemotweni?</td>
</tr>
<tr>
<td></td>
<td><em>There are three people in a car. Four more people get into the car. How many people are there in the car altogether?</em></td>
</tr>
<tr>
<td><strong>Change unknown</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kukho iimango ezisebhaskithini. Kuze kongezwe iimango ezintlanu ebhaskithini. Ngoku ibhaskithi ineemango ezilithoba. Bezingaphi iimango ebezisebhaskithini?</td>
</tr>
<tr>
<td></td>
<td><em>There are some mangoes in the basket. Five mangoes are added to the basket. Now there are nine mangoes in the basket. How many mangoes were there in the basket to begin?</em></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Collection (different attributes)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Collection unknown</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Subset unknown</strong></td>
<td>Kukho abantwana abathandathu eklasini. Abantwana ababini ngamakhwenkwe. Abanye ngamantombazana. Mangaphi amantombazana aseklasini?</td>
</tr>
<tr>
<td></td>
<td><em>There are six children in the classroom. Two of the children are boys. The rest are girls. How many girls are there in the classroom?</em></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Compare (more than)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compared quantity unknown</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Difference unknown</strong></td>
<td>Inkwenkwe ineeswiti ezilithoba. Intombazana ineeswiti ezilishumi elinanye. liswiti zentombazana zininzi ngeeswiti ezingaphi kwezenkwenkwe?</td>
</tr>
<tr>
<td></td>
<td>A boy has nine sweets. A girl has eleven sweets. How many more sweets does the girl have than the boy?</td>
</tr>
<tr>
<td></td>
<td>[Additional question]</td>
</tr>
<tr>
<td><strong>Referent unknown</strong></td>
<td>Umama unabantwana abasixhenxe, abeenoreni ezimbini. Kufuneka iimoreji ezingaphi ukuze umama akwazi ukunika umntwana ngamnye iorenji enye?</td>
</tr>
<tr>
<td></td>
<td>A mother has seven children, and she has two oranges. How many more oranges does mother need so that each child gets one orange?</td>
</tr>
<tr>
<td></td>
<td>[Additional question]</td>
</tr>
<tr>
<td></td>
<td>Umama uneembiza eziisibhozo neziciko ezihlanu. Ushota ngeziciko ezingaphi?</td>
</tr>
<tr>
<td></td>
<td>A mother has eight pots and five lids. How many lids is she short? [Additional question]</td>
</tr>
</tbody>
</table>
EXPLORING STUDENTS’ UNDERSTANDING OF LAPLACE TRANSFORM IN SOLVING LINEAR ORDINARY DIFFERENTIAL EQUATIONS

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Abstract
The purpose of this study is to investigate factors related to understanding underlying principles that cause students to have difficulty in solving nonhomogeneous linear ordinary differential equations using the method of Laplace transformation in a University of Technology in South Africa. This is one of the essential mathematical tools for solving ordinary differential equations with boundary values, such that it converts differential equation into an algebraic equation which are considerably easier to manipulate. The Laplace transformation is one of the methods that can be used to solve the second order linear and ordinary differential equations (ODE) with the given boundary conditions (Kreyszig, 2006). The concept of Laplace transform plays an important role of converting differential equation into linear algebraic equation which becomes easier to solve using the appropriate property of the table of Laplace transform. Once the solution is found in the Laplace transform domain, the inverse Laplace transform is utilised to get the solution to the differential equation. Although Laplace transforms is an important mathematical tool in many branches of engineering and science, (Grubbström & Tang 1999) pointed out that, it has essential applications in other fields of study. According to Bernhard & Carstensen (2002), the tool has proven to be quite difficult, yet it has a special importance for engineering mathematics students. The Laplace transform is a broadly used integral transform with various applications in physics and engineering. It is a powerful tool for analysing system models consisting of linear differential equations of higher order with constant coefficients. In physics and engineering, it is used for analysis of linear time-invariant systems such as electrical circuits, harmonic oscillations and mechanical systems. The Laplace transform is an essential tool that generates solution of linear constant coefficient differential equations extremely ease.

This paper examined the following research question: What kinds of errors do engineering students in the University of Technology make when solving ordinary differential equations using Laplace transform? How are these errors distributed? The study focuses on results obtained from an analysis of students’ examination scripts of semester II, 2015. The question on solving differential equation using Laplace transform was selected for this paper because it present students with difficulties in the examination. The results discussed in this paper are based on the analysis of examination scripts which were coded for the errors students typically committed and cognitive resources responsible for these errors and misconceptions. The resources generally include the knowledge structures of mathematical cognitive resources that students invoked in their reasoning.
The analysis of examination scripts for students’ errors and misconceptions in solving second order linear ordinary differential equation using Laplace transform, in the study is guided by concepts of Sfard theory (1992). Sfard suggested that, concepts in mathematics can be regarded effectively as a process and mechanically as an object. Accordingly, profound understanding of the concept requires students to observe mathematical concepts both as a process and as an object (Sfard, 1992). Learning of mathematics can also be considered in terms of the achievement metaphor and the contribution metaphor (Sfard, 1994). According to Sfard (1994), an achievement metaphor considers knowledge accumulation as learning that is progressively improved and blended to form valuable cognitive structure. With the achievement metaphor, students can acquire knowledge or may not. In the achievement metaphor, learning is viewed individual activity, such that the student in his or her mind is supposed to dynamically creates meaning of the cognitive structures. On the other hand, learning is not to be attained in the contribution metaphor, however, it is contribution in a new body of knowledge (Lea & Nicoll, 2013). In mathematics in particular, students try to overcome challenges in understanding concepts through creating their own body of knowledge which may not necessarily correct. Sfard and Linchevski (1994) claimed that these students established a pseudo-structural understanding. According to Sfard and Linchevski, pseudo-structural understanding implies students’ challenges to associate various mathematical conceptions in building a sound object knowledge, resulting to the expression of errors and misconception. Qualitative research approach on this study, is chosen more than the others since we would be able to illustrate logical observation in students’ responses on question of Laplace transform from their examination scripts (McMillan et al, 2014). This research is looking for errors and misconceptions that students displayed on the following systematic measures and establish the fundamental causes thereof.

- Laplace transform, definition and basic techniques
- Partial fraction expansion and simultaneous equations
- Inverse Laplace transforms and solution of differential equations.

The population for this study was Mathematics III Electrical Engineering students from a university of technology in South Africa. Focussed sampling was used to choose Electrical Engineering students in this university since, Mathematics III is a requirement to obtain a diploma certificate. Students set for the examination, had been taught by a professor who has more than 15 years of teaching experience in Mathematics III in the university especially at the diploma level. He is more of a traditional approach teacher, who used chalk and duster in the classroom for teaching purposes with the supplement of tutors. Ethical issues were taken into consideration since students' names from the examination scripts were withheld and only codes were used.

The data was collected from the analysis of November 2014 examinations' scripts for Mathematics III Electrical Engineering students from a university of technology in South Africa. Number of scripts analysed was 81 from a total of 120 students who set for the examination of November 2014 in this university. The examination scripts analyses focussed on students' errors in solving ordinary
differential equations with the given initial values. This study focuses on students' errors in solving the following differential equation using Laplace transform method:

\[
\frac{d^2q}{dq^2} + \frac{dq}{dt} + 5. y = 17 \sin 2t
\]
given that \(y(0) = 0\) and \(y'(0) = 0\)

In connection with research questions, data analysis followed the work of Kiat (2005) to categorise three types of errors that occur when solving second order linear ordinary differential equations using the method of Laplace transforms. The research questions were analysed by identifying and noting the frequencies of the following types of errors: conceptual, procedural and technical errors in mathematics.

The research presented in this paper is a focused study specifically tailored to measure students' errors on solving differential equations using Laplace transform method and its impact on their achievement. The study explored whether students' content knowledge of facts and procedures have different effects on their achievement, relative to knowledge of concepts and knowledge of the concept of Laplace transform. Overall, the study shown that mathematics III engineering students at a UoT make numerous errors in solving linear differential equations with constant coefficients using the method of the Laplace transform, due to inadequate conceptualisation. Lack of understanding of Laplace transform concept lead to weak interpretation that has led to procedural and technical errors which eventually contribute to students' poor performance. The results of this paper, showed that students tend to consider routine learning and hence they learn by rote rules of Laplace transform without attempting to master the concept (Skemp, 1987). Perhaps emphasis on relational and concept understanding in teaching the concept of Laplace transform would assist.

Our findings in the measure on Laplace transformation, definition and basic techniques provide evidence for previous studies which indicate that students' errors are not deliberate, instead, they are frequently based on procedures used systematically (Cox, 1975; Ben-Zeev, 1998). For instance, understanding student’s thinking in solving a mathematical problem contribute immensely in understanding their underlying challenges (Hunt & Little 2014); (Baldwin & Yun, 2012).

The partial fraction expansion and simultaneous equations as a second measure in the analysis of students’ errors in this study, has shown that students will keep on making procedural errors if they do not obtain aimed instruction to concentrate on those errors. We support the view of Fisher & Frey (2012) that error analysis can assist in targeting exact misunderstandings instead of re-teaching the entire concept. In this measure, we also established that simply teaching the formula of partial fraction expansion and the steps to solve simultaneous equations is naturally not sufficient to assist students’ improve conceptual understanding (Sweetland & Fogarty 2008). The analysis of the students’ examination scripts indicates that the sources of the challenges in the learning of Laplace transform is either lack of understanding or knowledge to use of table as a strategy to show relational
understanding of inverse Laplace transform and solution of differential equations (Fisher & Frey, 2012; Riccomini, 2014).

Based on the findings, we recommend that conceptual understanding of Laplace transform needs to be foregrounded before procedural and technical knowledge. In the classroom, teachers must provide valuable instruction to tackle the students’ specific errors. They should also be able to choose an operational strategy that will assist to remedy the students’ misunderstanding.
TECHNICAL MATHEMATICS: A New Mathematics or a New Version of Mathematics in the South African School Curriculum?

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Abstract

This paper presents analysis of Technical Mathematics curriculum which was introduced in 2016 in the Further Education and Training Phase (FET) as a third alternative mathematics to choose from in Grades 10-12. The paper draws from Graven’s (2002) orientations of mathematics knowledge and Bernstein’s (1971) notion of curriculum types to compare and contrast Mathematics and Technical Mathematics curricula in order to determine similarities and differences between the two subjects. The analysis shows that there are many similar topics between the two subjects. Both Mathematics and Technical Mathematics offer 10 main topics offered in the FET. Furthermore, analysis shows that there are only three new topics, angles and angular movement, integration and complex numbers which have been introduced in Technical Mathematics curriculum and as such never existed in Mathematics school curriculum. I argue that Technical Mathematics though it is said to be taken by learners who are taking technical subjects, there is no evidence to suggest that Technical Mathematics will offer special skills and specialised knowledge for technical schools that which was not offered by the ordinary CAPS Mathematics.

Introduction

The South African Department of Education (DBE) introduced the National Curriculum Statement (NCS) in the Further Education and Training (FET) (Grades 10 – 2) in 2006. Twenty-nine (29) subjects were introduced, including new subject Mathematical Literacy (ML) thus opening opportunity to all learners to do either Mathematics or Mathematical Literacy. There were however mixed views about the status and role of Mathematical Literacy whether it has any future career linked to it beyond school level (Mthethwa, 2014). Since 2006 when NCS was introduced there has been a public quest for another mathematics programme to be introduce for technical occupational streams. Introduction of two new subjects: Technical Mathematics and Technical Sciences was promulgated through a Government Gazette on 18 July 2014 and are being incrementally implemented in January 2016 in Grade 10, in Grade 11 and 12 in 2017 and 2018 respectively. In this regard, Technical Mathematics can only be taken by learners who are doing Technical subjects such as Technical Science, Engineering (DBE, 2014). This study provides an analysis of Technical Mathematics curriculum in relation to ordinary Mathematics curriculum.
Literature review

This study intends to understand the intended Technical Mathematics curriculum for Grades 10-12. According to TIMSS (1996) the intended curriculum consists of the mathematics and science that society intends students to learn, and the education system that society believes is best designed to facilitate such learning. Cuban (1995) refers to the intended curriculum as the official curriculum, and describes it as what state and district officials set forth in curricular frameworks and courses of study. This study draws from the previous studies on the analysis of South African Mathematics curriculum (Parker, 2006; Mwakapenda, 2008).

Theoretical framework

The official curriculum documents, i.e. Curriculum and Assessment Policy Statements (CAPS) for both Mathematics and Technical Mathematics were analysed using Graven’s (2002) orientation of mathematics as an analytical framework and Basil Bernstein’s conceptual framework of curriculum types. Graven (2002) Mathematics for critical democratic citizenship, Mathematics is relevant and practical. Mathematics as induction into what it means to be a mathematician, to think mathematically and to view the world through a mathematical lens. Mathematics as a set of conventions, skills and algorithms that must be learnt. Bernstein (1971) describes two broad types of curriculum, namely, the collection type and the integrated type. These types are related to what Cornbleth (1990) refers to technocratic curriculum and critical curriculum respectively. According to Bernstein (1971) a collection type “exists if the contents are clearly bounded and insulated from each other” (p.87). The following aspects were central in the analysis: definitions, aims (general and specific) of the curriculum, content and progression.

Methodology

This study sought to understand Technical Mathematics in relation to Mathematics curriculum for Grades 10-12. The qualitative research approach was adopted for its relevance to this study. It is argued that a qualitative approach uses a naturalistic approach that seeks to understand phenomena in context-specific settings (Hoepfl, 1997). Strauss and Corbin (1990) contend that qualitative methods can be used to better understand any phenomenon about which little is known, in this context Technical Mathematics curriculum. Data was collected through document analysis. Document analysis is a form of qualitative research in which documents are interpreted by the researcher to give voice and meaning around an assessment topic (Bowen, 2009). For this study, CAPS documents for Mathematics and Technical Mathematics Grades 10-12 were analysed.

Results

The study found that the definition of both subjects is the same except there is an additional aspect in the definition of Technical Mathematics that it applies the science of mathematics to the Technical
field where the emphasis is on application and not on abstract ideas. The general aims of the two subjects are the same and the specific are also similar except that Mathematics has eight (8) and Technical Mathematics has 11 of which the first 8 are similar to the Mathematics specific aims and the additional three (3) aims emphasise the role of Technical Mathematics in sustaining the other technical subjects and also preparing learners for the work place. Notably, one specific aim of Technical Mathematics states that it can only be taken by learners offering a Technical subject. Analysis shows that the main mathematics topics such as Algebra, Calculus, Financial mathematics, Analytical Geometry, Trigonometry and Euclidean Geometry are also present in Technical Mathematics curriculum. Furthermore, Technical Mathematics has additional topics not offered in ordinary CAPS Mathematics curriculum; these are, angles and angular movement, complex numbers and Integral calculus. On the other hand, a number of topics which offered in mathematics are not offered in Technical Mathematics. These are: - Statistics, probability, patterns, sequences and series. Progression in Technical Mathematics is structured in the same way as in Mathematics. With the exception of few topics, for example, integral calculus which is introduced only in grade 12, analysis shows that most topics (about 90%) are dealt with in Grades 10 and 11.

Discussion

In term of Graven’s orientations of mathematics, Technical Mathematics primarily subscribe to Orientation 1, i.e. Mathematics for critical democratic citizenship as such, It empowers learners to critique mathematical applications in various social, political and economic contexts and Orientation 2, i.e. Mathematics is relevant and practical as It has utilitarian values and can be applied to many aspects of everyday life. In terms of Bernstein’s notion of curriculum type, Technical Mathematics falls between collection type and integrated type. The aim of Technical Mathematics is to apply mathematics science in the real-life context thus suggest a weak classification though its actual content knowledge remains strongly classified.

Conclusion

While the department of basic education provides that the aim of Technical Mathematics is to apply the Science of Mathematics to the Technical field where the emphasis is on application and not on abstract ideas, it remains unclear how this aim will be achieved using the same content used in ordinary CAPS Mathematics.

References


EXAMINING ‘TEACHERS’ SPECIALIZED CONTENT KNOWLEDGE’ THROUGH AN ANALYSIS OF TEACHERS RESPONSE TO STUDENTS ERROR AND THEIR THINKING IN THE FRACTIONS CONTENT IN BAUCHI STATE NIGERIA

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Abstract
This study examines teachers’ Specialized Content Knowledge of fraction at the upper basic level in Bauchi State Nigeria. The population of the study comprised of all upper basic mathematics teachers in Bauchi metropolis. One research question was formulated to guide the study. Thirty-three (33) upper basic mathematics teachers were selected from 24 schools within Bauchi metropolis. The instruments used for data collection was Specialized Fraction Knowledge Assessment (SFK). The research question was analysed using a rubric developed by the researcher. Frequency and percentages were used in analysing the research question. Findings of the study revealed that upper basic teachers possessed limited Specialized Fraction Knowledge. Therefore, the study recommended for the strong need of urgent professional development of teachers with specific focus on specialized fractional knowledge for the upper basic mathematics teachers.

Introduction

Sufficient mathematics knowledge plays a significant role in shaping teachers’ quality of their teaching (Ball & Bass 2003). What kind of knowledge mathematics teachers need to know to teach mathematics effectively has been presently an issue of discussion in the international literature. The initial categorization of teacher knowledge emanates from the work of Shulman (1986, 1987). Shulman seminal work in 1986 discussed seven (7) categories of teacher knowledge. The last three categories were focuses on content knowledge, which sparked lot of interest in the current research in mathematics teacher education literature: Subject matter knowledge, pedagogical content knowledge and knowledge of curriculum. Many researchers in mathematics education have developed Shulmans’ ideas in the field of mathematics education for example, Ball, Themes and Phelps (2008) contextualized Shulmans’ work in the field of mathematics education, and they further provided more clarification on the distinction between subject matter knowledge (SMK) and pedagogical content knowledge (PCK). Ball, Themes and Phelps (2008) categories SMK in to common content knowledge (CCK), specialized content knowledge (SCK) and the horizon content knowledge (HCK). However, of particular interest in this study is their notion of specialized content knowledge which is seen as “mathematical knowledge and skill unique to teaching” (Hill, Schilling and Ball). Example of such knowledge is that teacher need to understand where the student makes an error and also be able to explain his or her thinking. Much research has been done on specialized content

**Instrument**

In order to examine teachers specialized content knowledge teachers’ specialized fraction knowledge assessment was developed which comprises five (5) wrong answers on fractions, the teachers were asks to indicated whether is wrong or right and to explained what is the student thinking thirty-three (33) teachers teaching mathematics at the upper basic level formed the complete data set. After retrieving the instrument, based on their responses on the instrument we were able proposed four (4) hierarchical ability levels as follows: level 0 (Problematic); at this level the teacher unable to recognized student error and provide any explanation of his or her reasoning. Level 1 (Emergent) teacher can recognized student error and provide explanations that does not connect with the student reasoning. Level 2 (Potential) teacher can recognized student error and provide correct explanation that connect with the student reasoning. But it appears to be potential within the context of the given problem. Level 3 (Well- articulated) teacher can recognized student error and provide sufficient explanations that connect with the student reasoning and extent beyond the immediate example space to more general.

**Table1: Rubric for Analysing Teachers’ Specialized Fraction Knowledge**

<table>
<thead>
<tr>
<th>Components</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level0 (Problematic)</td>
</tr>
<tr>
<td>Ability to recognized student error, and explained his/her reasoning</td>
<td>Teacher unable to recognized student error and provides any explanation of his/her reasoning</td>
</tr>
</tbody>
</table>

**Literature Review**

Many researchers have work on specialized content knowledge at different content in mathematics for example Ball & Bass (2009) in their finding shows that majority of the US teachers were un able solve multiplication of fractions correctly and provide accurate representations. Pino- fan & Godinoy Font (2011) their work on derivative indicated that only one teacher provided a formal solution using the derivative meaning as an instant rate of change for all the four items, the results also shows that teachers manifest difficulties to solve tasks related not only to specialized content knowledge but also with the common content knowledge. Miguel, Batenero, Diaz & Fernandes (2012) work on probability, their findings indicated that the participants possessed poor common and specialized knowledge of elementary probability. Branwin (2016) in her M Tech work on teachers’ specialized content knowledge of equal sign shows that teachers lack skills to prevent, reduce or correct
misconceptions about equal sign. Escudero, Flores & Carrillo (2004) developed a model of professional knowledge known as teachers’ specialized knowledge the results indicated that the use of these models helps the teacher to demonstrate effectiveness in teaching. Carrillo, Climent, Contreras & Miguel (2017) developed analytical model for determining specialized content knowledge the results indicated that the model enables the teacher to plan highly productive learning opportunities for his or her student. Many studies had been done in determining or developing models of analysing and examining teachers’ specialized content knowledge at different content in mathematics. But little had been done in Nigeria in view of that the present study investigated teachers’ specialized content knowledge through an analysis of teacher response to student error and his or her thinking in the context of fractions.

Methodology / Results

In order to comment on the teachers’ attainment across levels 0 to 3 we considered levels 0 and 1 as limited attainment, while levels 2 and 3 as satisfactory in terms of their specialized content knowledge. And we ask the following question what are the levels of teachers’ specialized fraction knowledge. The table 1 revealed that none of the teachers were found to be at level 0 (Problematic). But majority were at level 1 (Emergent) which constituted 61% of the participant. 39% were at level 2 (Potential) and none of the teachers is at level 3 (Well-articulated). The findings indicated that 61% of the teachers possessed limited specialized fraction knowledge, while 39% had satisfactory specialized fraction knowledge.

Table 2: Levels of Teachers’ Specialized Fraction Knowledge Component of SFK

<table>
<thead>
<tr>
<th></th>
<th>Level 0 (Problematic)</th>
<th>Level 1 (Emergent)</th>
<th>Level 2 (Potential)</th>
<th>Level 3 (Well-articulated)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to recognized student</td>
<td>0(0%)</td>
<td>20(61%)</td>
<td>13(39%)</td>
<td>0(0%)</td>
<td>33</td>
</tr>
<tr>
<td>error and explained his/ her</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>reasoning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusion / Recommendation

The study examines teachers’ Specialized Content Knowledge through an analysis of teachers’ response to student error and his or her thinking at the upper basic level in Bauchi State Nigeria. the results indicated that majority of the upper basic mathematics teachers possessed limited Specialized Fraction Knowledge. Based on the finding the study, recommended that there is strong need for continues teacher professional development programs for Upper basic mathematics teachers on teachers’ Specialized Content Knowledge.

References


THE EFFECT OF DIAGRAMMATICAL REPRESENTATIONS ON LEARNERS’ PROBLEM SOLVING COMPETENCY: Trigonometric Functions and Equations

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Abstract
This exploratory study investigates the effects of diagrammatic representations on learners’ problem-solving competencies. The study focuses on the transformation of a textual problem situation into a diagrammatic and vice-versa. A mixed structured test consisting of five trigonometric word problems, differing in their story context and structure, was administered to a randomly selected group of grade 12 learners (n = 125) from Sekhukhune District in South Africa. Focus group interviews were held to obtain further views about diagramming. Results showed that learners do not prefer diagrams during problem solving. Learners’ low of diagrammatic efficacy limits them in effectively presenting their arguments during problem solving. Learners have a challenge of switching from a word problem format to diagrammatic representation. The results also revealed that the learners do not prefer to use diagrams but other strategies such as algebraic approaches. The implications of the findings are discussed.

Keywords: Diagrammatical representations, Problem Solving, Trigonometric Functions, Trigonometric Equations.

Introduction

The use of diagrams provides alternative tools for problem solving promotes learners’ efficacy when solving problems (Manalo, Uesaka and Chinn, 2017). A diagrammatic representation of a mathematical concept combines related information together and enhance comprehension. Diagrams enhance engagement in learning and the development of essential mathematical skills such as communication, knowledge construction, creative reasoning, and representation (Uesaka and Manalo, 2012). A number of researchers identified specific problems relating to learners’ use of diagrams as: failure to draw appropriate inferences from a diagram (Manalo and Uesaka, 2016), learners are reluctant to use diagrams as problem solving tools (Booth and Koedinger, 2012), poor choice of diagrams to use and drawing small diagrams (Maries and Singh, 2017). Learning from visually presented information makes concepts more explicit and requires less inferential recognition than sentential representations (Purchase, 2014).

The use of diagrams as communication tools in mathematics teaching and learning is efficacious and should be cultivated in most classes. Abstract mathematical concepts are not easy to understand
without a simple representation. Quillin and Thomas (2015) emphasises that attention should be paid to how learners embrace different representational formats such as diagrams. Although diagrams facilitate problem solving, Schneider, Rode and Stern (2010) argued that information represented diagrammatically sometimes confuse learners. Furthermore, learners lack skills of interpreting diagrams and this impacts negatively on their learning of mathematics. Murata (2008) added that for effective learning to occur from diagrams, learners should have experience and prior knowledge and a strong background and familiarisation with different visuals. Bremigan (2005) maintained that the ability to construct new diagrams in learners’ solutions is related to successful problem-solving. However, Naftaliev and Yerushalmy (2013) argue that diagrams should be used with caution, as they do not stimulate reasoning and do not function as problem-solving tools because they may not represent the whole mathematical structure of the situation.

Learners learn better by seeing a pictorial model of as concept. Solving a problem by drawing a diagram helps to transform a problem into a representation that provides a clue for solving it. Drawing a diagram is a recommended approach for representing a word problem, particularly as learners work towards higher levels of mathematics in middle or high school grades (Van Garderen and Scheuermann, 2015). In mathematics, diagrams serve as external aids that facilitate problem cognition. Diagrams also serve as thinking and communication tools without which memory, thought and reasoning are all constrained (Meirelles, 2013). Diagrams provides representation concreteness and connects concepts with their referents (Fyfe et. al, 2014). The diagram represents the problem in a way the solver can see, understand and think about it (McQuade, 2010). By representing the problem visually, learners can begin to think about the problem and connect pieces of information (Diezmann, 2002).

The use of diagrams to solve mathematics problems help learners at all levels of mathematics learning (Stylianou, 2010). At elementary level, diagrams are used for recording information about the problem during the solution process. Once learners acquire the problem conceptualisation stage of problem solving, a diagram becomes a tool for exploring alternative ways of understanding the problem. At advanced levels of problem solving, a diagram helps to monitor and evaluate the solution. Despite their usefulness, generating diagrams remains a challenge for many learners (van Garderen, Scheuermann and Poch, 2014). Decoding verbal information and translating it into visual form requires learners to identify and synthesize information before connecting it to prior knowledge. Identifying and producing an accurate diagram appropriate for the context of the problem is a challenging process. The use of diagrams improves problem-solving speed and also provides a point of reference for learners to check their work for accuracy (Chu, 2015). Diagrams also scaffold algebraic reasoning by facilitating connections between concrete and symbolic representations (Booth and Koedinge, 2010). Diagrams are also beneficial to learners who are still developing familiarity with abstract symbols.

The aim of this study is to investigate the effects of diagramming on learners’ problem-solving competencies. There is a dearth in knowledge about how diagrams positively or negatively facilitate
problem solving. Extending the problem representation to diagrammatic representation provides insight into how learners interpret and solve problems. The focus of this study is on the transformation of a textual problem situation into a diagrammatic or schematic representation. The study explores mathematics learners’ use of diagrams in solving trigonometric problems.

**Problem statement**

The use diagrams as alternative mathematical problem-solving tools is recommended in most curricula. This recommendation is based on the assumption that diagrams are powerful tools that invoke mathematical thinking and learning. However, for some learners, this suggestion is unhelpful. Learners are reluctant to use diagrams and do not perceive diagrams as alternative problem-solving tools. Learners perceive diagrams as representations which are superfluous and disconnected from the problem they are solving. Learners prefer algebraic problem-solving approaches (Waller and Le Doux, 2014). They lack skills of constructing diagrams that integrate existing relations in word problems. Most learners do not use all the quantitative information contained in the word problem, therefore drawing diagrams referring to the context of the problem may help to solve the problem without relating to the data. This is the most difficult step and a large proportion of learners register failure in this endeavour.

Boaler et al (2016) noted that teachers continue to present mathematics as abstract subject. Instead, teaching through visual approaches, offers learners access to deep and new understandings. According to McQuade (2010) the first step in understanding a problem is to draw and label a figure, diagram or a graph. Teachers need to empower learners to utilise diagrams as problem solving tools. This paper explores learners’ efficacy and knowledge about diagrams and identifies some of the difficulties that learners experience in their use of diagrams.

**Research question**

This study is guided by the following research questions:

a) How does the diagrammatic representational formulation of a mathematical problem affect learner performance and solution strategy?

b) How are the solution strategies of learners affected by the diagrammatic representation used in the problem?

**Theoretical Framework**

This study is guided by the Cognitive theory of Multimedia Learning (CTML) which proposes that multimedia learning occurs when we build mental representations from words and pictures (Mayer, 2010). The Cognitive theory of Multimedia Learning (CTML) is an amalgamation of three models: Baddeley’s model of working memory, Paivio’s dual coding theory, and Sweller’s theory of cognitive load. The core idea of the cognitive theory of multimedia learning theory is that learners attempt to
build meaningful connections between words and pictures and that they learn more deeply than they could have with words or pictures alone (Mayer, 2010). According to CTML, one of the principle aims of multimedia instruction is to encourage the learner to build a coherent mental representation from the presented material. The role of the learner is to make sense of the presented material as an active participant, ultimately constructing new knowledge.

Methodology

This study employed qualitative approach. The goal was to provide a description of learners’ problem-solving competency with diagrams. To this end, the study attempts to explore the learners’ opinions through a written test and focus group interviews. Since this study explores the way learners utilise or avoid diagrams during problem solving, a case study with qualitative research techniques was pursued.

Participants

Participants for this study consisted of male and female grade 12 learners (n = 125) (78 females and 47 males) randomly selected from secondary schools around Sekhukhune District in Limpopo Province in South Africa. The learners were taught relevant trigonometric equations and graphs by integrating algebraic and graphical methods. A test based on the two approaches was administered after five teaching and learning sessions. The test results were analysed focusing learners’ interpretation of graphs, ability to draw graphs and spontaneity to use a graph as a problem-solving approach. Forty-five learners were selected and divided into 3 groups to participate in focus group interviews. Each group consisted of 15 learners and focus group sessions lasted from 1.5 hours to allow full exploration of the phenomenon. The researcher was the moderator and maintained a neutral position towards participants’ opinions. Participants for the focus group interviews were purposely selected based on their performance in the written test. Learners’ responses were analysed to determine their level of competence and efficacy with diagrammatic representations.

The Research Instrument

The instruments for this study consist of a self-constructed test and focus group interviews. The test was administered to 125 respondents in order to investigate how they utilised or not utilise diagrams (graphs) to answer trigonometric problems. The questions assessed learners’ interpretation diagrams as well as construction of diagrams as part of problem-solving approach. Learners were required to identify solutions of trigonometric equations on graphs that were already drawn or to draw graphs to solve equations. The test consists of 5 questions designed with respect to the above targets. In question 1 the aim was to assess if learners could interpret and use a diagram to establish trigonometric relationships. Questions 2-4 were designed to assess learners’ ability interpret graphs and respond to questions based on their graphs. The last question (5) assessed learners’ spontaneity to initiate a graph as a strategy to solve the problem. Furthermore, focus group interviews were held
to obtain rich data about learners’ diagrammatic efficacy, learners’ responses were directly quoted, and their statements add further meaning to the interpretation of study results. Interview notes were used to understand learners’ thoughts during problem-solving.

Data Analysis

Content analysis was adopted as a data analysis technique for this study. Content analysis refers to the method where the content extracted from learners’ work form the basis for drawing inferences and conclusions about how they perceive diagrams during problem solving. Content analysis is a qualitative data analysis method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns (Hsieh and Shannon, 2005). The researcher extracted content from texts to examine meanings, themes and patterns. When examining learners’ responses, the researcher emphasised on skills such as analysing diagrams and extracting main concept, drawing diagrams, graphical spontaneity and choice of diagrams to use.

Results and Discussion

The questions assessed learners’ skills to extract ideas from graphs and use of graphs as problem-solving tools. Their answers were evaluated in the context of these skills.

Question 1

A camera is placed on top of a building at point A. It shows two vehicles parked outside the building. The angle of elevation of point A from vehicle D is $\theta$. Vehicle C is equidistant from vehicle D and the building. Let $x$ denote the distance DC and $CDB = \beta$.

i. Draw a detailed diagram to represent this situation.

ii. Prove that $AB = 2x \cos \beta \tan \theta$

The first question assessed the learners’ analytical skills of transforming textual problem situation into a diagrammatic or schematic representation. The learners were expected to draw a diagrammatic representation of the situation and solve the problem from the resulting visual representation. The results of the learner responses to this question show that only 21 (16.8%) managed to draw diagrams and use them to answer the questions. Sixty-six (52.8%) did not attempt to draw the diagram and could not respond to the other parts of the question. The other 30 (30.4%) drew incomplete or partial diagrams which they could not use to respond to the other sections of the question. Eight (6.4%) incorrectly responded to the questions without making reference to a diagram even though they were instructed to use diagrams. These findings show that learners do not use diagrams spontaneously and do not perceive the efficiency of their use as an alternative problem-solving strategy. The findings are consistent with Uesaka, Manalo and Ichikawa (2007) who noted that learners do not appreciate diagrams as alternative problem-solving tools.
Question 2

Given \( f(x) = a \sin(bx + c)^\circ + d \) and \( g(x) = p \cos(qx + r)^\circ + s \)

1. Determine the values of \( a, b, c, d, p, q, r \) and \( s \) and hence the equations of \( f \) and \( g \)

2. Read from the sketch, the values of \( x \) for which \( f(x) = g(x) \) for \( x \in [0^\circ : 180^\circ] \)

The second question assessed the learners’ skills of interpreting diagrammatic or schematic representation of trigonometric functions. Learners were expected to interpret information from a graph and use it to respond to a set of questions. Firstly, they were required to use the graph to find the equations of the graphs and later use the graphs to solve the equations. Thirty-four (27.7%) responded to the questions correctly while 91 (72.8%) experienced interpretation challenges. Learners could not read off the values of unknown variables from the graphs hence the equations were incorrect and consequently, it was not easy to estimate and confirm the solutions of the equations. Learners’ responses indicate that they do not make sense of those representations spontaneously if they lack knowledge of the mathematical concept embedded in the diagram. Thus, one can conclude that at times diagrams do not convey a mathematical concept directly into the learners’ minds, but they have to be actively interpreted. Prior knowledge of the concept and it diagrammatic representation is therefore essential for conceptual understanding. Steenpaß and Steinbring (2014) also emphasised that the diagram’s single elements have to be correlated with each other and interpreted as parts of a complex symbol system to become meaningful.

Question 3

The third question assessed the learners’ skills of interpreting diagrammatic or schematic representation of trigonometric functions. Learners were expected to interpret information from a graph and use it to respond to a set of questions. Furthermore, the questions required learners to transform the given graphs to new graphs based on their interpretation of the transformation notation. The main focus of the question was on interpreting the graphs in order to find the parameters.
Learners’ responses indicate that they do not use all the information given in the diagram as evidenced by learners who disregarded the domain of the functions and give solutions which were out of the given range. Fifty-four (43.2%) learners correctly interpreted the graphs and solved the equations successfully while 71 (56.6%) participants lacked interpretation skills. Eight-four (67.2%) participants were successfully responded to last question on reflection along the y-axis despite incorrect values of the magnitude and period of $f(x) = a \cos bx$.

**Question 4**

The fourth question assessed the learners’ skills of interpreting diagrammatic representation of trigonometric functions. The main focus of the question was on interpreting the graphs in order to find the parameters. Furthermore, the question required learners to draw an additional graph on the same set of axis and use the two graphs to solve an equation. Furthermore, the questions required learners to transform the given graphs to new graphs based on their interpretation of the transformation notation. Learners’ responses indicate that they lack skills of constructing graphs. Fifty-one (40.8%) learners correctly interpreted the graphs and solved the equations successfully.
while 74(59.2%) participants lacked interpretation and drawing skills. The question on reflection was successfully answered.

**Question 5**

\[
\begin{align*}
  f(x) &= -\sin \frac{1}{2}x \\
  g(x) &= \cos x - 1 \\
  h(x) &= \sin x
\end{align*}
\]

(a) Describe in words the transformations which transform \(g(x)\) to \(h(x)\).
(b) Write down the period of \(f(x)\).
(c) Write down the amplitude of \(g(x)\).
(d) Make neat sketch graphs of \(f(x)\) and \(g(x)\) on the interval: \(-180^\circ \leq x \leq 180^\circ\), labeling intercepts and turning points. (Re-draw the grid below)

The last question assessed the learners’ analytical skills of transforming diagrammatic or schematic representation problem situation into a textual form. The learners were expected to interpret the visual representation format in words. Learner responses to this question show that 47 (37.6%) managed to correctly describe the transformations envisaged in the question while 78 (62.4%) did not attempt the question or failed to give the transformation. The graphs drawn by learners provide evidence that they lack graphing skills. Results indicate there are still serious problems with switching from a diagrammatic representation of a concept to a textual format.

**Conclusion**

The results indicate that learners do not perceive diagrams as useful problem-solving tools. Learners lack the skill of spontaneously constructing a diagram. They do not appreciate the benefits of using a diagram as an alternative problem-solving strategy. Participants’ responses indicate that they have problems with switching between the graphical and algebraic representations of trigonometric functions and equations. Learners do not pay attention to the relationship between graphs and their symbolic representations in order to determine the parameters which characterise their amplitude, period and transformations. Learners are concerned with the correct application of procedures involving some common representational forms at the expense of the demands of the question. Emphasis should be placed on creating graphs and using the information in the graphs to solve problems. Teachers should challenge learners’ prior knowledge of graphical representations and link it with symbolic notation during classroom discussions.
References


A NARRATIVE READING OF ANIMAL FARM FROM A MATHEMATICAL PERSPECTIVE

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Abstract

"Boxer was an enormous beast, nearly eighteen hands high, and as strong as any two ordinary horses put together", (pg. 2, Orwell, 1945).

“Food stuffs had increased by 200 per cent, 300 per cent, or 500 percent…”, (pg. 57, Orwell, 1945)

These excerpts from Animal Farm are examples of the many instances in which Mathematics especially numbers have been used in the book. It is possible that the author's intentions were not to present Mathematics or mathematical ideas, but because some story lines needed the use of mathematical language, he could not do without using Mathematics.

The purpose of this study was to find out learners’ ability to “see” mathematics and interpret mathematics from a non-mathematical specialised book, Animal Farm. The study sought to find out learners’ ability to read mathematically since Mathematics is a specialized language that requires a specialized domain of practice. Reading in this study was conceptualised as learners’ ability to see or identify and interpret the embedded ideas, concepts and connections from the printed page (Pretorius, 2008). Animal Farm was chosen because it was one of the English literature books for Grades 10-12 in South Africa in 2014 Academic year. The argument in this regard is that academic (generally) and mathematical (specifically) activities are incommensurate with everyday activities although academic mathematical knowledge is not commonly used as a theory for facilitating adequate or appropriate understanding of everyday practices (North & Christiansen, 2015).

The study collected both quantitative and qualitative data in three phases using three different questionnaires. The study used Dowling’s domains of mathematical practice as its theoretical framework. The theory gives a distinction between mathematical content that is highly organized at the level of language and content that generally lacks systematic organisation in language Dowling (1998).

Findings of this study showed that learners were not able to ‘see’ and identify Mathematics from Animal Farm in the first and second phases of data collection. They were only able to ‘see’ and identify Mathematics in the third phase of data collection when they were given excerpts with the concept of number from Animal Farm. However, learners were still unable to interpret the excerpts like the ones presented above to show their understanding of both the excerpt and the mathematical aspect of it.
I concluded that learners lacked a “mathematical gaze” to enable them see mathematics embedded in the story. Their comprehension skills were also weak to enable them to interpret mathematical aspects as they appeared in Animal Farm.

Introduction

This study investigated Grades 10 to 12 learners’ ability to see, identify and interpret Mathematics in reading materials other than Mathematics textbooks. The study explored learners’ perspectives and interpretations of mathematical aspects found in Animal Farm. The study assessed learners’ abilities to ‘see’, identify and interpret mathematical aspects from Animal Farm.

Three key questions examined in the study were:

1. What reading resources (written textbooks and otherwise) are (made) available to secondary school Mathematics learners in multilingual contexts?
2. What are the connections between what learners are reading and school mathematical knowledge?
3. To what extent are the learners able to see the connections?

Theoretical framework

Dowling (1998) identified four domains of mathematical practice; esoteric, expressive, descriptive and public domains to distinguish how Mathematics content and expression of the content are used in Mathematics practice. Table 1 below summarises the four domains:

<table>
<thead>
<tr>
<th>Domain of mathematical practice</th>
<th>Mathematical content</th>
<th>Mode of expression</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esoteric</td>
<td>Strong</td>
<td>Strong</td>
<td>$2x + 3y = 5$</td>
</tr>
<tr>
<td>Expressive</td>
<td>Strong</td>
<td>Weak</td>
<td>Find the probability of getting 2 heads and 1 tail when 2 coins are tossed</td>
</tr>
<tr>
<td>Descriptive</td>
<td>Weak</td>
<td>Strong</td>
<td>Find the total cost of 8 loaves of bread if one loaf costs K800</td>
</tr>
<tr>
<td>Public</td>
<td>Weak</td>
<td>Weak</td>
<td>We travelled on a muddy road for 2 hours</td>
</tr>
</tbody>
</table>

What this means is that the esoteric and expressive domains have a strong degree of specialization of mathematical contents which can unambiguously be identified as Mathematics (North & Christiansen, 2015). The descriptive and public domains on the other hand have weak degree of Mathematics content such that Mathematics appear to be something other than Mathematics ‘Mathematics parading as something other than itself’ (Dowling, 2013).
In this study, the mathematics that learners were supposed to identify in Animal Farm can be classified as public domain mathematics. The author of Animal Farm was using his own public and familiar language to present the story. He used his familiar mathematics content and mode of expression in the story.

**Study methodology**

The study collected both qualitative and quantitative data, most of which were qualitative. Data was collected from Grades 10-12 learners from five schools in three provinces in South Africa using three different questionnaires in three phases.

**Findings of the study**

In phase one of data collection, I found that the reading materials available to secondary school learners were mostly school textbooks in science, Mathematics and English. These books were made available to learners by their schools. In phase 2 of data collection, most learners were unable to explain how Animal Farm is connected to Mathematics and to identify mathematics from the book. In phase 3, deliberate efforts were made to extract statements with the application of the concept of number and asked learners’ questions based on these aspects.

Learners were asked if there was any Mathematics in the given excerpts. They were supposed to indicate yes for ‘Mathematics’ and no for ‘no Mathematics’ in the excerpt. Table 2 below shows the results:

<table>
<thead>
<tr>
<th>Excerpt</th>
<th>Yes (%)</th>
<th>N</th>
<th>No (%)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lose an hour’s sleep</td>
<td>94 (78)</td>
<td>6 (5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Eighteen hands high</td>
<td>92 (71)</td>
<td>8 (6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Two ordinary horses put together</td>
<td>93 (75)</td>
<td>7 (6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. First rate intelligence</td>
<td>83 (66)</td>
<td>17 (14)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. A thousand times no</td>
<td>91 (42)</td>
<td>9 (4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Throughout the short remainder of your lives</td>
<td>51 (22)</td>
<td>49 (21)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Five times in succession</td>
<td>93 (39)</td>
<td>7 (3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. The whole farm burst into singing</td>
<td>73 (33)</td>
<td>27 (12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Every drop of it</td>
<td>60 (24)</td>
<td>40 (14)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Approaching middle life</td>
<td>65 (26)</td>
<td>35 (14)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 shows that more than 80% of the learners were able to identify Mathematics in the excerpts that had an explicit connection to the concept of number. For extracts that had an implicit connection to the concept of number, the percentages were lower.
**What does the excerpt mean?**

After identifying the Mathematics part of the excerpt, learners were asked to give the meaning of the excerpt to show their understanding of the excerpt. Table 3 below is an example of learners’ responses on the meaning of the excerpt “Boxer was eighteen hands high and strong”

**Table 3: Boxer was eighteen hands high and strong**

<table>
<thead>
<tr>
<th>Excerpt</th>
<th>Meaning of the excerpt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boxer was eighteen hands high and strong</td>
<td>1. describing how high he was</td>
</tr>
<tr>
<td></td>
<td>2. eighteen people raise their hands to measure someone</td>
</tr>
<tr>
<td></td>
<td>3. he was helping or giving a hand to others</td>
</tr>
<tr>
<td></td>
<td>4. raising hands and count up to 18</td>
</tr>
<tr>
<td></td>
<td>5. tall by eighteen hands</td>
</tr>
<tr>
<td></td>
<td>6. the height takes up to 18 hands</td>
</tr>
<tr>
<td></td>
<td>7. the size of someone</td>
</tr>
<tr>
<td></td>
<td>8. there were 18 hands by measurement</td>
</tr>
<tr>
<td></td>
<td>9. too tall and strong</td>
</tr>
</tbody>
</table>

Table 3 above shows learners’ interpretation of the given excerpt. In this excerpt the number eighteen is being used to show the size of the horse called Boxer. I expected learners to explain the meaning of the excerpt in relation to how they imagined the height of Boxer who was 18 hands high or indeed to explain the meaning hands as used in measurement.

Some learners could not see or identify number words in all the three phases of data collection. This finding raises the question: what does it take for one to see Mathematics? Adams (2003) defined Mathematics reading as reading words, numerals and symbols in order to uncover the message of and about Mathematics. In this study, learners were supposed to read mathematically in order to uncover the message of mathematics. However, the results showed that:

1. The learners had weak “mathematical gaze” to enable them to see mathematics beyond the Animal Farm story
2. The author used public domain mathematics in Animal Farm. However, what was public, familiar and everyday experiences to the author was not public and familiar content and mode of expression to the readers. They readers had difficulties to interpret what the author meant.
3. The learners’ comprehension skills were weak.

**References**


CURRENT SITUATION OF ZAMBIAN CHILDREN’S GUIDED-PLAY IN AN EARLY CHILDHOOD EDUCATION PRE-MATHEMATICS CLASSROOM: A CASE STUDY

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ABSTRACT
This paper describes the current situation of and challenges in early childhood mathematics education in Zambia. First, it identifies the status of in-class practices, including pedagogical challenges, in a case study. Second, it assesses children’s learning through play using a typology of development theories and educational approaches as its theoretical framework.

Keywords: Mathematics; Early childhood education; Zambia; Playing; Guided play

INTRODUCTION

Early Childhood Education (ECE) in Africa has been the subject of extensive study and debate. This is true in the case of Zambia, as well. The private sector had frequently been involved in the field of preschool education (Ministry of Education, 1996) until the publication of the new curriculum framework and syllabus (Curriculum Development Centre, 2013; Ministry of Education, Science, Vocational Training, and Early Education, 2013). Lusaka, the capital city of Zambia, and the remote areas in Livingstone in the Southern Province, are the centres of the expansion and development of ECE in the country. Although there were only eight ECE classes in Lusaka in 2017, the number is steadily increasing. In the international community of mathematics education, various types of studies on preschool mathematics education have been conducted (e.g. Brandt 2013; English & Mulligan 2013; Lin et al. 2013; Clements & Sarama 2009). In the field of education, learning through play has been considered an important strategy for children to grow both mentally and physically and seen as a vehicle for learning (Vogt et al. 2018; Hauser 2005; Singer 2013). However, the meaning and interpretation of playing at the implementation level differ depending on various social and cultural conditions (Bishop, 1991; 2000), which have not been examined at the ECE level in Zambia. Addressing this gap, this paper examines current classroom practices in Zambia in order to discuss specific pedagogical challenges, develop a lesson for mathematical guided play on shapes, and discuss what and how children learn through the proposed and implemented activity. In doing so, this study provides evidence of how guided play can contribute to quality mathematics education in the Zambian context.
LITERATURE REVIEW

Many studies have demonstrated that ECE plays a crucial role in shaping children’s later developmental outcomes (Duncan et al. 2007; Thomas, et al., 2011; Weisberg et al. 2013; Vogt et al. 2018). An increasing number of studies have discussed the development of ECE programs in different countries (Müller & Wittmann, 2004a; 2004b; South African Numeracy Chair Project 2016), enhancement of teachers’ pedagogical content knowledge (Lee 2017; McCray & Chen 2008), the professional development of teachers (Warren & Quine 2013), and so on. Playing is crucial for the physical and mental development of young children (Froebel, 2015). Consequently, the national curricula and syllabi of some countries, including African countries (e.g. Japan, Germany, Australia, Kenya, Zambia, and South Africa), emphasize the importance of playing in teaching and learning. However, little is known about early childhood mathematics education in Sub-Saharan Africa. It is also important to consider the sociocultural perspectives that affect play in order to implement activities related to playing. This section provides a brief overview of early childhood mathematics education in Zambia and the applicability of guided play for this study.

ZAMBIAN PRESCHOOL MATHEMATICS

Introducing ECE in 2004, Zambia has since expanding its quantitative aspect countrywide, particularly in the capital city of Lusaka and the outskirts of Livingstone. The Ministry of Education, Science, Vocational Training, and Early Education (2013; 2014, p. xi) states that the objective of ECE in Zambia is to help children acquire the knowledge, skills, attitude, and positive values necessary to attain developmental milestones. ECE comprises two learning sections: the nursery level for three- to four-year-olds and reception level for five- to six-year-olds. Social Studies, Environmental Science, Language and Literacy, Pre-Mathematics, and Expressive Arts—which comprise the so-called core curriculum—are the major learning areas, and are equivalent to the subjects taught in primary school (Ministry of Education, Science, Vocational Training, and Early Education 2014, p. 36). In addition, children are expected to acquire certain competencies, such as naming, making relationships, problem solving, exploration, experimentation, numerical and other mathematical activities, and a sense of time, which are strongly related to mathematics learning (Ministry of Education, Science, Vocational Training, and Early Education 2013, p. xiii). Moreover, the syllabus emphasizes that young children should learn through playing and that teachers should offer them the opportunities to explore their surrounding environment. Prospective preschool teachers are advised to experience playing themselves in order to ensure that they encourage children to explore their environment (Curriculum Development Centre, 2016; Ministry of Education, Science, Vocational Training, and Early Education 2013).

The pre-mathematics reception level aims to develop children’s mathematical knowledge, skills, and values and develop their interest in mathematics for everyday use (Curriculum Development Centre 2016; Ministry of Education, Science, Vocational Training, and Early Education 2013). Children should learn mathematics through objects that can be manipulated; therefore, the learning should be
practical. Pre-mathematics at the reception level comprises algebra, numbers, geometry, measurements, as well as commercial arithmetic, which pertains to monetary operations.

CONCEPTUAL FRAMEWORK: GUIDED PLAY

Weisberg et al. (2016) note that the role of play in ECE has been controversial in terms of the dichotomy between learning and play (Clements & Sarama 2014). The most subjective play is called free-play, while the least subjective play is implemented through direct instruction (Weisberg et al. 2013). Weisberg and colleagues (2013) discuss the middle ground of the two contrasting types of play: namely, guided play. Its theoretical base respects exploration, investigation, and children’s autonomy with teacher-guided instruction (Fisher et al. 2011; Weisberg et al. 2013). Guided play is effective when certain learning goals are devised and when children need to learn new material with the help of adults. In mathematics learning, young children can become familiar with the mathematical concepts from their surrounding environments through free play. However, they also need to learn new concepts that they have not seen before in the classroom setting, as some mathematical concepts cannot be understood without adult assistance or intervention. In this case, guided play works well. In guided play, the guidance of teachers or adults is crucial (Weisberg et al. 2013) because their support determines whether the guided play can lead children to meet the educational objectives set in class. As such, in addition to using a formal lesson structure (as in primary school education) while incorporating free play, guided play is in line with Zambian ECE mathematics. Therefore, this study concentrates on a typical pre-mathematics class to examine how guided play functions for children’s learning.

METHODOLOGY

Data collection was done in Lusaka from 6–9 March 2017, in four urban schools where the preschool sections were open. There were only eight government schools opened for ECE, and reception classes were attached to governmental primary schools. The purpose of the data collection was to access the information of early childhood mathematics education since no research papers had dealt with the theme, as well as to reveal the current status of lessons and pedagogical challenges in class. Ethically, the study was permitted by the Ministry of General Education and also these schools. The school head teacher and class teacher agreed to provide the information for this study.

This study utilized the framework known as the typology of developmental theories advanced by Montada (2008) and Vogel (2013). This framework is useful for analysing instructional practices in mathematics teaching and learning. Table 1 displays the typology of development theories supplemented by educational approaches. Vogel (2013) states that educational approaches can adhere to different models, guiding the actual pedagogical work, the formation of learning environments, and everyday interactions among children and their learning environment. There are four models and approaches to understanding the interactions between subject and environment: interactionist transactional systemic models that facilitate co-construction, actional and
constructivist models based on self-education, exogenist models that focus on (co-operative) mediation, and endogenist models based on self-development.

Table 1. A typology of development theories and educational approaches

<table>
<thead>
<tr>
<th>Environment</th>
<th>Active</th>
<th>Inactive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
<td>Interactionist transactional</td>
<td>Actional and constructivist models</td>
</tr>
<tr>
<td></td>
<td>systemic models</td>
<td>→ approach of self-education</td>
</tr>
<tr>
<td></td>
<td>→ approach to co-construction</td>
<td></td>
</tr>
<tr>
<td>Inactive</td>
<td>Exogenist models</td>
<td>Endogenist models</td>
</tr>
<tr>
<td></td>
<td>→ (cooperative) approach of</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mediation</td>
<td></td>
</tr>
</tbody>
</table>

(Vogel 2013, p. 210)

In the interactionist transactional systemic model based on co-construction, both children and their environment—including teachers, friends, and other educational facilities such as mathematical games—should be active in learning. This model leads the approach to co-construction and is suitable for play-based learning; Vogel (2013) argues that the concept of educational scaffolding brought this to bear in mathematical situations of play and exploration. Therefore, using Vogel’s (2013) different models, the author examined how the instructions in class could be categorized into the four different models and educational approaches. Methodologically, the study was conducted as a case study. The data were obtained through lesson observations and informal discussions with school administrators and teachers, as well as a curriculum specialist in the Curriculum Development Centre under the Ministry of General Education. The lessons and interviews were recorded through note-taking and a DVD camera. Later, the author watched the observed lesson. The author also took notes to record how and what the children learned through the activity.

FINDINGS

Data collection

All four of the primary schools involved in the data collection had one class for reception with five-to six-year-old children in ECE. This seems typical of governmental schools, since every school visited followed this format and an ECE specialist at the Curriculum Development Centre mentioned the limited capacity of government primary schools to build new sections for ECE within or outside them. However, private ECE schools included classes for three different age groups: day care for two-year-olds, nursery for three- to four-year-olds, and reception. In all the schools, a teacher set up a timetable, and a thirty-minute pre-mathematics lesson was conducted four to five times a week. In school A, the teacher instructed the students to make numerals out of clay. In school B, a student-teacher led the activity alone; pupils received a certain number of beads and pointed to the corresponding numeral and drawings of concrete items on the wall. They also sang songs related to
mathematics and finally played a game called ‘Chato’, which is a traditional game using stones and a
circle drawn on the floor. In school C, children first learned how to write numerals corresponding to
a given number. Then, they sang a song related to the days of the week and played a game by clapping
their hands in the direction of the number said by the teacher. In school D, the student-teachers
divided children into four groups, directed them to create shapes using coloured blocks, and some
children presented their work. Subsequently, they sang a song and danced during several lessons. All
the observed activities are shown in Table 2.

Table 2. Activities observed in schools

<table>
<thead>
<tr>
<th>Schools</th>
<th>Activities</th>
<th>Form of leaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>(i) To make numerals with clay</td>
<td>Whole class and individual work</td>
</tr>
<tr>
<td>B</td>
<td>(ii) To match numbers of beads with numeral and concrete objects (iii) To sing a song (iv) To play a traditional game</td>
<td>Whole class and group work</td>
</tr>
<tr>
<td>C</td>
<td>(v) To learn how to write numerals corresponding to numbers (vi) To sing a song (vii) To play with hands and numbers</td>
<td>Whole class</td>
</tr>
<tr>
<td>D</td>
<td>(viii) To play with blocks and understand the common attribute of shapes (ix) To sing and dance to a song</td>
<td>Group work</td>
</tr>
</tbody>
</table>

The observed lessons had two tendencies. Some lessons consisted of the main activity for fifteen to thirty minutes and teachers offered songs or simple play activities before/after the task, while other lessons comprised a combination of short activities. In both cases, teachers controlled when children should focus in class. In all of the lessons, teachers neither summarized the activities nor assessed their activity. Table 3 shows these activities according to the analytical framework. The activities were categorized based on the degree of each teacher’s class control, students’ remarks and physical activity, as well as the class contents.

Table 3. Assessment and classification of activities

<table>
<thead>
<tr>
<th>Subject</th>
<th>Environment</th>
<th>Active</th>
<th>Inactive</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
<td>(ii), (iii), (iv), (vi), (vii), (ix)</td>
<td>(i), (viii)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inactive</td>
<td>(v)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 shows that activities (ii), (iii), (iv), (vi), (vii), and (ix) are related to the approach to co-construction; (i) and (viii) are related to approach of self-education; (v) is related to the cooperative approach of mediation; and that no activities were related to the approach of self-development. Thus, the observed lessons had many activities related to the approach to co-construction. In (i) and (viii), pupils were supposed to quietly create things while the teacher kept quiet. In (v), the author generally observed interactions between the teacher and children and, in contrast, the teacher controlled the class throughout. The activities included in the approach to co-construction can be
grouped into physical play [(ii), (iv), and (vii)] and singing songs [(iii), (vi), and (ix)]. In the first category, (ii) and (v) had similar learning characteristics: teaching to the entire class as children were active and talkative, getting beads from a box, pointing to pictures on the wall, and saying the numbers in class. Pupils were engaged in these activities. As for (iv), the teacher did not say anything but made some circles and divided the children into different groups for play. Children were engaged and counting during the game; the environment and the subjects were mutually interacting. In (vii), the teacher did not point out who was right or wrong, but children themselves realized it during the game. Using their bodies, such as by clapping their hands and jumping at certain times, proved effective in their learning of numbers. This indicates that singing and dancing could be an effective tool for children to learn mathematics. Thus, with the exception of (ii), which seemed to be more formal learning than playing, the activities offered the children enjoyable methods for learning mathematics.

However, pedagogical challenges were also apparent. First, mutual interactions between the children were rare during these activities, and the teacher controlled the class. Greater emphasis could be placed on pair and group work. These characteristics are very similar to the teacher-centred approaches followed in primary schools, which are also observed in other African classrooms (Arthur 1996; Ackers & Hardman 2001; Bunyi 1997), and this may be related to sociocultural norms in Zambia. For instance, in the case of (ii), the teacher always pointed to a pupil who came to the front to choose the beads, and pupils followed teachers’ direction, given less space for playing with beads. Or pupils could have point out the other child to do the activity. This type of mutual learning, giving authority to children and letting them decide things to do would enhance the values emphasized in the syllabus overview (Ministry of Education, Science, Vocational Training, and Early Education, 2014, p. xi).

While teachers led many activities related to playing, they could decrease their control, thereby encouraging the children to become more engaged in play. Moreover, there were no summaries or reflections on the lessons, and no feedback was gathered from the children. From the point of view of mathematics education, the teacher could recognize the children’s ideas or actions that are mathematically important during their activity, and the children could discuss their impressions and findings. These reflections would be useful for children’s motivation as well as learning assessment.

CONCLUSION

This study revealed that the lessons of early childhood mathematics education in Zambian reception classes already include many physical activities involving teacher–pupil interactions, and that these are often related to Zambian cultural practices such as traditional games, singing, and dancing. However, these activities lack mathematical contents. This study also clarified that some classroom practices are similar to those of primary classes, where the teacher controls the pupils. Thus, while confirming that ECE approaches and the implementation of play-based strategies are shaped by sociocultural context, this study indicates that greater attention needs to be placed on directing activities towards subject specific content in order to achieve more effective learning. In the future,
this study can be extended to develop other play-based activities with teachers and examine the effectiveness of the interventions.

ACKNOWLEDGEMENT

I would like to express my gratitude to the teachers and principal of the preschools where this study was conducted. The study was funded by the Japan Society for the Promotion of Science research grant no. 15H02911. Finally, I would like to thank Editage (www.editage.jp) for the provision of English language editing services.

REFERENCES


WHAT ARE THE IMPLICATIONS OF THE NBTP QUANTITATIVE LITERACY TEST RESULTS FOR TEACHERS?
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Students intending to enter some Higher Education (HE) institutions in South Africa, write the National Benchmark Tests (NBT) to provide a measure of their readiness for HE. Numerous school-leaving learner are underprepared for HE and contribute to the fact that only 35% of the total intake of HE institutions’ graduate within five years, while an estimated 55% never graduate (CHE, 2013). This article explores the following research question: Which quantitative literacy competencies that are required in Higher Education, as identified through the National Benchmark Test Project (NBTP), are not well developed by test writers and what are the implications thereof for teachers? A considerable body of literature now points to the poor performance in the quantitative literacy (QL) tests of the NBTP like Bohlmann, Prince and Deacon (2017) as well as Bansilal (2017). However, this paper seeks to take this a step further. It will use data from a large study of the QL test responses to point to ways in which teaching in the schools can address the problems identified in the tests. In the study twelve out of fifty test item results in which students performed the poorest, were analysed (N=2348). A mixed method approach was used to analyse the data where the principles of the Classical Test Theory and the Item Response Theory were used as the basis for the statistical analysis. The incorrect responses were also analysed to assess which possible misconceptions were revealed. The areas identified for teachers to focus on included quantity, number and operations, data representation and change and rates. The research reveals a number of issues that could be of assistance to teachers including presenting learners with more challenging tasks and the use of more authentic contexts in which to situate the numerical task.

Key Words: NBT, Quantitative Literacy Teachers; FET; Improve teaching.

Reference
CHE (2013).
EVALUATING AND REFINING ADAPTED MATHEMATICAL KNOWLEDGE FOR TEACHING INSTRUMENT USING ITEM RESPONSE THEORY
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Application of Item Response Theory (IRT) is common among researchers interested in educational achievements using paper-and-pencil tests. In this paper, I demonstrate how we applied IRT to evaluate and refine adapted Learning Mathematics for Teaching (LMT) measures. Data was collected by administering the adapted measures to 212 pre-service primary school teachers. A 2PL IRT model was used to calibrate the items and the results were used to construct shorter version of the adapted instrument with twenty-two items. The items varied in their discrimination (slope) (0.18 to 1.33). Their difficulties (location) mirrored a substantial range of MKT (ability) (–3.46 to 4.98). However, the items as a set were most discriminating at higher levels of MKT. We argue that when used correctly, IRT is an effective tool for evaluating and refining instruments.

Rationale

Teachers’ effectiveness is attributed to several factors. Studies have shown that subject knowledge is fundamental to teacher competence and teaching practice (Hill, Rowan, & Ball, 2005). Great strides have been made since Shulman’s maiden work on content knowledge. Specific to mathematics, Ball and colleagues identified the fundamental tasks of mathematics teaching (e.g. Ball, Thames, & Phelps, 2008). Their work culminated into the development of the MKT framework and associated LMT items to measures. The measures have been adapted to different contexts including Ghana (Cole, 2012). While the LMT measures have been validated comprehensively and adapted internationally (Hoover, Mosvold, Ball, & Lai, 2016), their reliability cannot be assumed to be attainable in all contexts. This study reports how I used IRT to evaluate the performance of adapted LMT measures in our contexts.

Item Response Theory in Brief

IRT is a system of models for establishing the relationship between a construct and its manifestation (de Ayala, 2009). It models the relationship between an individual’s response to an item and his/her ability. Hambleton, Swaminathan and Rogers (1991) note that the two-parameter logistic (2PL) model is often applied for items with dichotomous response options. The 2PL model produces item characteristic curves (ICCs) that are described by the location (b) and slope (a). These parameters discriminate one item from another. The b-parameter (difficulty) is the point along the ICC at which the probability of a correct response to an item is 0.50. A larger b indicates that a respondent must
have more of the measured construct to respondent correctly to that item. Usually, the level of the measured construct a person has is denoted $\theta$ (Embretson & Reise, 2000). According to Embretson and Reise, $a$ represents the slope of the ICC at $\theta = b$ and indicates the extent to which the item relates to the measured construct. A steeper slope (i.e. bigger value of $a$) indicates a closer relationship to the construct and therefore a more discriminating item. Models suitable for items with more than two response options exist. While these polytomous models differ from dichotomous parameterization, all models include the difficulty and discrimination parameters (de Ayala, 2009). A discussion on how to choose a model is beyond the scope of this paper. However, suffice to say that I used a 2PL model because the items had dichotomous responses. Regardless of the number of item responses, Hambleton, Swaminathan and Rogers contend that the item properties from IRT calibration can be useful in scale development and refinement.

Another significant aspect of IRT models is that reliability is defined as a continuous function conditional on $\theta$. Reliability is described by item information curves which show the values of $\theta$ over which respondents are best discriminated by an item. These curves are a function of the item parameters and can be calculated for individual items, sets of items, or entire instrument. This feature is useful in evaluating the performance of individual items, group of items, and therefore critical in the construction of tailored assessment instruments or selecting items that provide desirable levels of reliability (de Ayala, 2009).

Methodology

I selected and adapted LMT items from existing instruments by aligning the items to our local contexts. I observe rigor in the adaptation process and IRT was applied to evaluate the adapted items.

Data were collected from 212 primary school pre-service teachers using an adapted instrument. The instrument had forty-six items that examined knowledge for teaching number concepts and operations. Each item was classified as either common content knowledge (CCK) or specialized content knowledge (SCK) (Ball, Thames, & Phelps, 2008) or both.

All the participants had completed secondary school and held a school certificate of education. The participants were in the first year of their teacher education programme. The participants’ responses were scored using BILOG software. IRT analyses were done to estimate, for each item, the slope ($a$), location ($b$) parameters among others. I used the parameters to identify problematic items and hence refine the adapted instrument.

Results and discussion

The summary statistics for parameter estimates are in Table 1. The range of slopes estimates show a sizable variation in item discrimination. The location values reflect a wide range in the level of MKT among the participants. However, most of the items were only correctly responded to by participants.
with higher than average levels of MKT (\(\theta > 0\)) suggesting that the instrument was most useful in discriminating among participants at the high levels of the MKT.

Table 1. Summary statistics for parameter estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>No. of items used in calibration</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>46</td>
<td>0.18</td>
<td>1.33</td>
<td>0.38</td>
<td>0.17</td>
</tr>
<tr>
<td>b</td>
<td>46</td>
<td>-3.46</td>
<td>4.98</td>
<td>1.36</td>
<td>1.96</td>
</tr>
</tbody>
</table>

Table 2. Distribution of item difficulties

<table>
<thead>
<tr>
<th></th>
<th>(-2 \leq b &lt; -1)</th>
<th>(-1 \leq b &lt; 0)</th>
<th>(0 \leq b &lt; 1)</th>
<th>(1 \leq b &lt; 2)</th>
<th>(2 \leq b \leq 3)</th>
<th>(b &gt; 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local</td>
<td>3</td>
<td>5</td>
<td>9</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>U.S.</td>
<td>12</td>
<td>16</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

The b-values for all items, mean 1.36, were slightly skewed to the left (-0.34) suggesting that a fair number of the difficulties were on the right of the \(\theta\)-scale. This shows that the participants found most of the items difficult. The actual distribution of the difficulties was such that two items had difficulties below -3, and eight with difficulties above 3. Table 2 shows the distribution of the item difficulties locally compared to the U.S. While comparison was not the purpose of this study, the table helps to show how the items performed in terms of item difficulty. Items with \(b < -3\) (very simple) and \(b > 3\) (very difficult) (Embretson & Reise, 2000) were considered problematic hence were either removed or refined.

Figure 1 shows ICCs for two items. I use these items to exemplify how ICCs vary depending on the slope parameter (item 14 has a fairly high slope, \(a = 0.53\), than item 15 with \(a = 0.19\)), and the location parameter (item 14 is endorsed at low levels, \(b = 0.92\), than item 15 with \(b = 3.6\)). These values suggest that the respondents found item 15 relatively difficult than item 14. The IICs in Figure 2 demonstrates how measurement reliability across the \(\theta\)-scale is affected by these parametric variations. Item 14 has higher slope and reaches maximum information level within \(-3 \leq \theta \leq 3\). However, item 15 does not only provide very low information but has also very poor discrimination owing to its higher location parameter. This item was therefore removed. Following this procedure and considering item’s point biserials (not discussed here), a total of fourteen items were removed.
Figure 1: Item Characteristic Curves (ICCs)

Figure 2: Item Information Curve (IICs)

Figure 3: Test Information Curves (TICs)

Figure 3 show the test/total information curves (TICs) for the first draft and revised instruments. The TICs show that the tests were most informative at MKT levels $\theta = 3.2$ and $\theta = 0$ respectively. This
indicates that while the first instrument was much suited for higher levels of MKT, the revised instrument can estimate MKT at average levels with reasonable degree of precision.

**Conclusion**

IRT analysis enabled me to analyze items and classify them based on their perceived level of difficulty and discrimination. I was able to identify problematics items and therefore refine my instrument either by revising or removing the problematics items. I conclude that, if used appropriately, IRT can help to design instruments that are both informative and reliable.

**References**


DEVELOPING PHYSICS TEACHERS’ PEDAGOGICAL CONTENT KNOWLEDGE: Reflection on a Lesson Study Intervention
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Abstract
This paper reports on the development of teachers’ pedagogical content knowledge during a modified lesson study intervention on the teaching of electricity and magnetism. Four teachers in rural and city schools in South Africa were conveniently selected to participate in the study. Data were collected through interviews, lesson observations, and reflective journals. The findings show an improvement in teachers’ pedagogic competence in developing lesson plans, as well as ability to reflect and evaluate on the quality of their classroom teaching. Furthermore, it was found participating in the intervention of lesson study enabled the teachers to implement teaching strategies promoting learners’ active learning.

Keywords: Electricity and magnetism, Lesson study, Pedagogical competencies, Reflection.

Research in physical sciences has grown considerably over the years and this implies that the knowledge base for physics teaching has clearly changed over time due to trends in scientific innovation and changes in science curricula. However, one of the fundamental purposes of physical science education in the 21st century is preparing learners to acquire and apply the scientific knowledge and skills required to thrive in today’s world. This is of particular importance in developing countries such as South Africa. Research indicates that physical science lessons are better understood when classes are by complemented strategies such as hands-on experiments and tasks that need learners to collaboratively view real life events (American Association of Physics Teachers (AAPT), 2013). Unfortunately, many teachers still use the one-way traditional lecture method and ignore the practical aspect of the science. Studies that investigated factors responsible for learners’ poor performance in physical science identified teachers’ pedagogical content knowledge (PCK) as a major factor that influences learners’ academic performance (Callingham, Carmichael, & Watson, 2016). The challenge thus become for teachers to transform their foundational knowledge for effective science teaching in the 21st century? In this regard, research have shown that the use of lesson study as a model of teachers’ professional development have the possibility to enhance teachers’ foundational knowledge in terms of content and pedagogy (Cajkler, Wood, Norton, Pedder & Xu, 2015) as well as improve their classroom practice (Dudley, 2013).

The discussion presented in this paper is a reflection on a larger study (Author, 2018). The study is grounded on the notion of PCK, which represents teachers’ understanding of how specific topics are
modified in terms of content and pedagogy and presented as instructions to learners of different abilities and interest (Shulman, 1987). It is this foundational knowledge that distinguishes the knowledge of a pedagogue from that of a content specialist (Shulman, 1987). However, there are other components such as knowledge of subject matter/content, knowledge of pedagogy, knowledge of learners and knowledge of curriculum, which informs the development of teachers’ PCK (Cochran, De-Ruiter, & King, 1993; Van Driel, Verloop, & de Vos, 1998). Thus, the aim of this paper is reporting on how teachers develop components of pedagogical content knowledge for teaching electricity and magnetism through participation in a lesson study intervention. The topic of electricity and magnetism was chosen as a vehicle for the study as difficulties to teach and learn these topics have been well reported (Hekkenberg, Lemmer, & Dekkers, 2015).

A qualitative case study approach was employed to gain an in-depth understanding of how teachers’ PCK for teaching electricity and magnetism developed within the context of a modified lesson study intervention. A purposive and convenient sample of four physical sciences teachers from three different South African schools participated in this study. It was difficult to find teachers who were willing to participate in such a demanding and extensive study. Eventually, four teachers were found but they were unable to function in a single lesson study group due to logistical reasons: two of the teachers were Grade 11 teachers from a rural school, while the other two were Grade 10 teachers from city schools. Therefore, the teachers worked in two independent lesson study pairs. Each pair participated in four phases of an adapted lesson study cycle. At the preparation phase, each pair of teachers identified learners’ difficulties in electricity and magnetism at the respective grade level they were teaching, and also planned lessons to address the difficulties identified. During the teaching phase, the jointly prepared lesson was taught by each teacher in his/her class while the researcher made observations and video recordings of the teaching. Differing from the Japanese model, the participants were unable to observe each other during the teaching phase due to their own teaching responsibilities dictated by the timetable and the demands of the curriculum. During the reflection phase, video recorded lessons were viewed and discussed by the pairs to improve subsequent lessons. Data were collected through interviews, lesson observations and reflective journals, and analyzed using content analysis.

Findings from the analysis and interpretation of data revealed that subtle guidance provided by the researcher as an outside expertise stimulated teachers’ awareness of learners’ difficulties and caused them to think about learners’ learning. Prior to teachers’ participation in lesson study, lesson plans were poorly prepared, content driven, and teacher centred with little provision for learners’ learning. However, during lesson study, teachers improved their lesson planning with more emphasis on what and how learners should learn at the end of the lesson. By the end of the lesson study intervention, a shift towards learner-focused teaching was accomplished.

Prior to lesson study, the teachers employed three variations of teaching strategies which includes direct teaching, explanation, and illustration to address learners’ difficulties in electricity and magnetism. During lesson study, learners’ engagement in guided problem-solving, practical activities,
and demonstrations were added to the teachers’ strategies. In spite of the contributions of the study, some limitations were also identified, which were related with the nature of investigation. For instance, evidence of teachers’ learning were based on observations and self-reports from participants’ interviews. No summative evaluation was conducted to assess the changes in teachers’ knowledge due to participation in this study. More so, the effect of teachers’ lessons on learners’ performance was not investigated. In addition, the case study design used in this study is not intended to give a general picture of what the situation is with other physical sciences teachers across South Africa. Nevertheless, the results indicate that lesson study can be used with benefit to teaching physics in rural as well as city schools in South Africa.

References


EXPLORING OF LEARNING STYLE PREFERENCES AND INSTRUCTIONAL STRATEGIES ON MATHEMATICS PERFORMANCE OF GRADUATING SENIOR SECONDARY SCHOOL STUDENTS IN DELTA STATE IN NIGERIA

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The frequency and steady decline of mathematics achievement of graduating senior secondary school students in West African Senior Secondary School Certificate Examinations (WASSCE) and National Examination Council (NECO) in Nigeria is creating fear, anxiety and concern among students, educators, stakeholders, researchers, parents and the government. It is essential, therefore, to conduct additional research identifying the extent to which learning style preferences influence mathematics achievement of students, particularly graduating senior secondary school students. Further, it is important to say that mathematics is a compulsory subject at the secondary school level and a requirement for proceeding to tertiary levels of education especially in universities despite anticipated career aspiration of students in Nigeria. In addition, a collective view of learning style preferences which encourages students to exercise their reasoning powers or imagination and active participation in mathematics classrooms could be effective and enhance students’ achievement in mathematics. This is line with Gauld (2011), who assert that teachers can create a learning environment that gives students opportunity to be active participants in the learning process and Orhun (2013), who opined that academic achievement of students can improve when teaching strategies or methods of teaching by the teachers are tailored to student’s learning style preferences. To this end, this study intends to explore the influence of learning style preferences on mathematics achievement of 450 graduating senior secondary school students in Delta State in Nigeria who are preparing for both April/May WAEC and NECO June/July 2017 Certificate Examinations. The study will employ a mixed methods approach and explanatory sequential mixed-method design will be used in collecting and analysing both quantitative and qualitative data. At the quantitative stage, data will be collected from written response of 450 participants preparing for both WAEC and NECO certificate examinations in the public secondary schools across the three senatorial districts (Delta Central, Delta North and Delta South) to two instruments namely; Kolb’s Learning Style Inventory (LSI) and Mathematics Achievement Test (MAT) as well as interviews with 24 best achieving students from mathematics achievement test. The data that will be generated from the 450 subjects in the quantitative part of the study will be collected, organized and analysed around the three research questions developed in the study using both descriptive and inferential statistics. For instance, Pearson Correlation Coefficient will be used to assess the relationship between the four learning styles, two-way Analysis of Variance (ANOVA) will be used to determine the level of significant interaction between gender and students’ preferred
learning style and one-way ANOVA will be used to determine the relationship between students’ learning style preferences and age. The individual interviews will be interpreted in the stages suggested by Wellington and Szczerbinski (2007):

- Immersion (reading and re-reading the transcripts)
- Reflecting (careful observations)
- Analyzing the data (coding)
- Recombining/synthesizing data (noting specific activities relevant to the research questions)
- Relating and locating data (comparing data with literature findings)
- Presenting qualitative data (integrating qualitative data with quantitative data).

The results of both quantitative and qualitative phases of the study will be discussed from the constructivists and experientialists learning theories perspective in order to answer the research questions.
Abstract

The practicum experiences of pre-service teachers (PSTs) take place under the supervision of school and university mentors. School mentors monitor the development of the PSTs in real-world conditions, all the while learning to teach in context; while university mentors clinically supervise and assess the extent to which the students are mastering their professional practice according the measures promoted in the university setting (Nyaumwe & Mavhunga, 2005). Crucially, the university and school mentors operate in different institutional spaces where educational ideologies and beliefs may differ: the university is usually a more progressive space, while the schools often prefer traditionalism (Hudson, 2007). This disjunction has the potential to lead to conflicting messages conveyed in the mentors’ feedback to the pre-service teachers (Nyaumwe & Mavhunga, 2005).

In this study, 4 PSTs were tracked during their practicums. Each PST was interviewed via semi-structured interviews and asked about their mentoring experiences. In addition, the mentors’ feedback sessions with the students were recorded. One PST in particular, received patently contradictory messages from his school and university mentors, regarding his practice during an observed lesson, suggesting that the mentorship space is a site of conflict between the school and university mentors, in terms of the ideologies they promote and the demands they make on PSTs. This conflicting feedback could impact negatively the emerging practice of the pre-service teacher.

Introduction

Pre-service teachers (PSTs) regard the practicum as the most important and relevant aspect of their teacher preparation (Mena, Hennissen & Loughran, 2017). They look to their school mentors to share their professional knowledge with them and to give them an authentic experience of what teaching entails. But what opportunities are these PSTs given to participate in authentic activities which can be regarded belonging to a community of practice? In the South African context, the practicum sessions are of relatively short duration, and are often described as extremely stressful by many PSTs. Are these PSTs given sufficient opportunities to participate in the practice of teaching and, through this participation, to become knowledgeable in and about the practice? The role of the mentors in this process therefore cannot be over-emphasised, especially as teacher education in general, and practicums in particular, take on varying formats.
Literature Review

The role and function of educational mentors is often seen as being important for quality mentoring. Mentors’ responsibilities include monitoring the development of the student in real-world conditions, all the while learning ‘to teach in the context of teaching’ (Cavanagh & Prescott, 2007). In addition to the school mentor, the university also assigns mentors to visit the PSTs at their practicum schools in order to clinically supervise and assess the extent to which the students are mastering their professional practice according to the (usually reform) measures promoted in the university setting (and taking for granted that the university’s message is conveyed uniformly and consistently!). Thus, the role of these mentors is to support, encourage, coach, give feedback and initiate PSTs into teaching (Nyaumwe & Mavhunga, 2005).

The differing contexts of school and university mean that the different mentors view the PSTs from different perspectives, and as such the mentors may differ in terms of what is taken as evidence and how the assessment criteria are applied. For example: while the university mentors may look for progressive and reform pedagogies (e.g. discovery learning and group work), the school mentors are usually satisfied with traditional ‘chalk-and-talk’ practice in a well-disciplined classroom. Moreover, the school mentors may believe they are in a better position to evaluate the students, given the greater contact time they have with the students during their practicum; the university mentors, meanwhile, see only snapshots of the students in practice (Cavanagh & Prescott, 2007).

Conceptual framework

Hudson (2007) designed a 5-factor model to analyse and describe the work of mentors. He believed that effective mentoring of PSTs is vital for their professional development and ‘cannot be left to chance’ (Hudson, 2007). The 5 factors in his model include: personal attributes (the mentor shows support, pays attention and assists the student in reflection); system requirements (the mentor discusses the aims of teaching mathematics as contained in curricular and policy documents); pedagogical knowledge (the mentor assists in lesson planning and implementation, teaching and assessment); modelling (the mentor models a lesson to demonstrate effective class management and mathematical discourse); and feedback (the mentor provides oral and/or written feedback on observed lessons). This model demands social interaction and conversation between the mentor and the student (Hudson, 2007; Cavanagh & Prescott, 2007). These mentoring conversations are a special kind of professional conversation regarded as a core activity in knowledge construction.

Talking about teaching allows PSTs to recognise and name the knowledge of practice; the PSTs’ knowledge construction can improve through this sort of participation.

Methodology
This paper draws on the author’s PhD study in which he tracked 4 Postgraduate Certificate in Education (PGCE) students during their practicums. The PGCE is a one-year exit certification qualifying the PSTs as professional teachers and consists of a university-based teaching methods component and practicum experiences. While a range of data was collected for the study, in this paper I draw on only the PSTs’ semi-structured interviews and the school and university mentors’ written and oral feedback to the PSTS. The school mentors were provided with the same assessment instruments designed and used by the university mentors. This is a standard practice in efforts to standardise the evaluation process and to try to ensure consistency (Nyaumwe & Mavhunga, 2005, p. 137).

Findings

All the school mentors provided general pedagogic feedback (written or oral), which focused on classroom management and student expectations. Some mentors also provided lesson plans and assisted with resources and class discipline when required. None of the school mentors were reported to have discussed the aims of teaching mathematics as per curricular or policy documents, or modelled exemplary lessons for the PSTs. Only one of the four PSTs had a mathematics specialist university mentor to evaluate their mathematics lessons, while the other three university mentors were not mathematics specialists. Thus, while all the university mentors echoed the school mentors’ generic pedagogical feedback, only one could (and did) provide feedback on the actual mathematical content and pedagogy.

I will use the case of Vuyo (not his real name) to illustrate the apparent conflict between school and university mentors. Vuyo had a very conscientious school mentor who provided daily written feedback to him. As much as this mentor appreciated Vuyo’s strong content knowledge, she was unhappy with his conversational style with the learners and his apparent lack of focus (her words: ‘he’s always jumping from one thing to the next’). After one particular lesson on exponents, her written feedback to him included the following (in capital letters and exclamation mark): ‘ALGEBRAIC AND GRAPHIC ARE TOO HARD!’ His university mentor (the mathematics specialist) encouraged Vuyo to use his strong content knowledge to extend the learners where possible and, during the same lesson, applauded his use of algebraic and graphic representations when dealing with exponents. This was the most obvious example of contradictory messages conveyed to the student by the mentors, which could have a disruptive effect on the student’s developing practice. However, the university mentor ended her feedback on a conciliatory note, by reminding Vuyo of the need to balance his own pedagogical choices with the school’s requirements.

Conclusion

The aim of this paper was to show that the mentorship space can be a site of conflict between the school and university mentors, in terms of the ideologies they promote and the demands they make on PSTs. All mentors drew the PSTs’ attentions to general pedagogic issues such as learner discipline,
providing clear explanations and consolidating after each section. Only the specialist mathematics university mentor provided specific feedback on the mathematics content and pedagogy, but this was clearly contrary to the school mentor’s feedback. There was also cause for concern for the three students who did not receive feedback on the mathematics content and who could be led to believe that they handled the mathematical content effectively, which may not always have been true.

The mentorship space is an uneven terrain in many South African schools. Given the importance of the practicum on the PSTs’ professional development, this could have detrimental effects on the quality of our next generation mathematics teachers.

References


The handbook is intended to provide teachers, researchers and education professionals with cutting edge knowledge developed in the last decades by the educational, behavioural and neurosciences, integrating cognitive, developmental and socio economic approaches to deal with the problems children face in learning mathematics. The neurocognitive mechanisms and the cognitive processes underlying acquisition of arithmetic abilities and their significance for education have been the subject of intense research in the last few decades, but the most part of this research has been conducted in non-applied settings and there’s still a deep discrepancy between the level of scientific knowledge and its implementation into actual educational settings. Now it’s time to bring the results from the laboratory to the classroom.

Apart from bringing the theoretical discussions to educational settings, the volume presents a wide range of methods for early detection of children with risks in mathematical learning and strategies to develop effective interventions based on innovative cognitive test instruments. It also provides insights to translate research knowledge into public policies in order to address socioeconomic issues. And it does so from an international perspective, dedicating a whole section to the cultural diversity of mathematical learning difficulties in different parts of the world.

The book is structured into four parts:

1. Development of Number Understanding: Different Theoretical Perspectives
2. Mathematical learning and its Difficulties around the World
3. Mathematical Learning Difficulties and its Cognitive, Motivational and Emotional Underpinnings
4. Understanding the Basics: Building Conceptual Knowledge and Characterizing Obstacles to the Development of Arithmetic Skills
5. Mathematical Learning Difficulties: Approaches to Recognition and Intervention

After a short overview, this snapshot review will then hone in on part 2 with a particular focus on our region. Chapter 15 ”Mathematical Learning and Its Difficulties in Southern Africa”, will be compared to trends in the rest of the world reported in Chapter 20 ”Adding all up: Mathematical Learning Difficulties Around the World”. 


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GRADE 9 LEARNER RESPONSES TO INTEGER QUESTIONS: A Mixed Methods Analysis
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Introduction

This study forms part of a larger study that investigates the impact of a professional development (PD) program offered by the Wits Maths Connect Secondary Project (WMCS). I focus on the errors made by the students of the teachers who participated in the PD. Consequently, the teachers and the PD are backgrounded in my study. Using a mixed methods approach, I investigated whether there are any significant relationships between the errors made on six integer items. I used contingency tables and conducted Chi-squared tests followed by Cramer’s V tests to determine the strength of the relationships found (Shishkina, Farmus, & Cribbie, 2018). Using literature, I then attempt to explain the relationships found. I report here on some preliminary findings.

In this paper I focus on two items: −6 + 5 and −6 − 5. Both have the same numerals and have a preceding negative (−6). The only difference is that 5 is added in the first and subtracted in the second. Being able to simplify such number sentences is an important precursor for algebraic questions such as “simplify −6a + 5a”, and “solve −6a + 5 = 5a + 6”. Previous research has identified common errors learners make with negatives numbers (Gallardo and Rojano (1990); Kieran (1992); Vlassis (2004)) but has not investigated whether there are relationships between the items and the errors made. My research therefore aims to address this gap by asking the question: What is the relationship between the errors made in items with a preceding negative?

Below, some of the common errors made when dealing with negatives as well as the reasoning that accompanies such errors are discussed.

Literature review

Research has shown that learners make many errors when dealing with negative numbers (Gallardo and Rojano (1990); Pournara, Hodgen, Sanders, and Adler (2016); Vlassis (2004)). One of the reasons for their errors stems from learners not being flexible with the different functions of the minus sign (Vlassis, 2004). Gallardo and Rojano (1990) argue that the minus symbol has a unary, binary and symmetric function. It is therefore not surprising that with multiple functions of the minus sign, learners produce many different errors.
The binary function is learners’ first encounter of the symbol. This is evident in number sentences and word problems that require subtraction, for example: $10 - 3 = ?$ or David has 5 sweets and gives 2 away, how many sweets does he have left? The symbol used here can be referred to as an “operational symbol” (Vlassis, 2004, p. 472). From a whole number point of view, learners would relate the binary meaning to ‘getting less’ (Galindo & Newton, 2017, p. 220) and obtaining positive solutions. The unary function of the minus sign is introduced to learners when they are introduced to negative numbers. This is where the minus sign no longer signals subtraction but rather identifies the structure of the numeral, hence being referred to as a “structural signifier” (Vlassis, 2004, p. 472). Learners who have not become flexible in dealing with the unary function are likely to apply the binary function instead. For example: $-10 + 6$ would be interpreted at $10 - 6 = 4$. Vlassis (2004) reports that learners often deal with negatives (or the unary function) by inserting mental brackets around some numbers to exclude the leading negative. Gallardo and Rojano (1990) refer to this type of reasoning as bracket reasoning. The third function is the symmetric function where the minus sign includes “taking the opposite of a number” Vlassis (2008, p. 561). This is evident in number sentences where learners are required to subtract a negative which results in addition, for example $10 - (-4) = 10 + 4$. In the multiplication of negative numbers, a negative number multiplied by a negative number also results in a positive number. Although producing the same results, when subtracting a negative (for example $10 - (-4)$), teachers may say that negative 1 is being multiplied by negative 4 which produced a positive, which ultimately leads to $10 + 4$. Kieran (1992) reported that learners overgeneralise this idea of “a negative and a negative make a positive” and apply it for example to $-6 + 5 \rightarrow (-6)(+5) \rightarrow -30$ or they multiply the signs and add the numbers: $-6 + 5 = -11$. This reasoning is referred to as the “signs rule”.

Sample and methodology

This study draws on 4950 learner test scripts collected by the WMCS team and myself. Using the Solo Taxonomy (Biggs & Collis, 2014), 45 test items were developed that covered Grade 8 and Grade 9 curricula content but were limited to integer work, substitution, simplifying expressions, factorising, equality, solving equations, function, and pattern. This study is only concerned with the items that relate to integer work. A subset ($n = 2075$) of Grade 9 learners from 37 township schools in Johannesburg were purposefully chosen out of the 4950 sample. The criteria used for the purposive sampling was that all six integer items need to have been attempted.

All raw responses were captured and their frequencies noted. Incorrect responses that were made by more than 10% of the learners were classified as ‘potentially significant errors’ and then labelled from Error 1 to Error 12. Contingency tables were created to show the frequency distribution (or proportion distributions) of errors in one item in rows and in another item in columns. Large frequencies (or proportions) suggest a relationship between the two error types. A Chi-squared Test was performed to determine whether there is in fact a significant difference between the variations of the errors learners made.
Results

Comparing each item to each other resulted in 15 contingency tables. From these, any relationship above 10% was considered significant. I focus here on the relationship between Item 3: \(-6 - 5\) and Item 6: \(-6 + 5\). The contingency table showed that 16% of learners who made ‘Error 13’ in Item 6 also made ‘Error 6’ in Item 3. Error 6 is \(-6 + 5 \rightarrow -11\) and Error 13 is \(-6 - 5 \rightarrow -1\). The Chi-squared Test produced \(p = 2.2 \times 10^{-16}\) which is very close to zero hence rejecting the null hypothesis and accepting the alternate hypothesis. This suggests that Item 3 and 6 are dependent. However, the \(X^2\) value is very high (\(X^2 = 169\)) with 16 degrees of freedom. The Cramer’s V test was therefore performed after the Chi-squared Test. The Cramer’s V Test determines the strength of the relationship that the Chi-squared test found. In relation to Item 3 and 6, the Cramer’s V test was 26%. This is classified as a weak relationship. From a qualitative perspective, the weak relationship is surprising. Based on the literature reviewed we can suggest that the error was made by inserting brackets in Item 3: \(-6 + 5 \rightarrow -(6 + 5) \rightarrow -11\) and in Item 6: \(-6 - 5 \rightarrow -(6 - 5) \rightarrow -1\). The signs rule (Kieran, 1992) could also apply to Item 3, but not to Item 6. In Item 3 learners could have reasoned by saying that a negative 6 and a positive 5 results in a negative number, and that since \(6 + 5 = 11\) the result of : \(-6 + 5\) is \(-11\). In Item 6 however if this rule was consistently applied learners would have obtained positive 1 as their solution rather than negative 1.

Conclusion

The statistical relationship found between Item 3 and 6 suggests that learners do indeed use bracket reasoning when there is a leading negative and so prompts deeper qualitative investigation (such as interviews with learners). In addition, knowing that the error is a common one, it is surprising that the statistical relationship is so weak. A statistical analysis on two integer items (Items 3 and 6) using contingency tables, a Chi-squared test and Cramer’s V test identified a statistically significant, although weak, relationship between two errors made. These errors can be found in literate and could be explained using bracket reasoning.

References


MATHEMATICS TEACHING IN CONTEXT

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INTRODUCTION

The majority of teachers have a general understanding that mathematics can be taught effectively and meaningfully without relating it to culture and history (Fasheh, 1997; Mogari, 2014). They perceive the mathematics curriculum as being academic, and contexts beyond the formal “word sum” are seldom used. Teachers are driven by a content-based syllabus (Rakgokong, 1993; Khumalo, Molepo & Mji, 2015). Learning largely took place through memorisation without understanding. Classroom mathematics is viewed and presented as absolute, abstract, pure and a universal body of knowledge (Cole, 2005). The ultimate goal of many teachers is to ‘cover the syllabus’ and to drill learners to pass the examination. Activity-based teaching is seen as time-consuming and preventing teachers from completing the syllabus in time. The ethos of mathematics teaching revolves around the syllabus and the matriculation examination. People interact with the world and attempt to comprehend, interpret and explain it using numbers, logic and spatial configuration which are culturally shaped (Powel, 2002; Onaifoh & Ekwueme, 2015). When mathematics is taught in a way detached from social and cultural aspects, and in a meaningless way, it is not only useless, but also very harmful to the learners (Presmeg, 2007). The learners’ background experiences and culture are considered crucial for meaningful learning to take place. They are extremely important factors to create more conducive learning environments in which it is easy for the learners to create their own meaning and understanding. The National Curriculum Statement provides opportunities for educators and researchers to see mathematics in ways that present mathematics as a discipline that has connections with everyday realities (Department of Education, 2001). This study is underpinned by Social Constructivism Theory that encourages learners to construct their own meaning and understanding of the world they live in. The study sought to explore the extent to which mathematical shapes or concepts of the traditional buildings of the Limpopo Province may be used to enhance the teaching and learning of mathematics in context and was guided by the research question: What challenges do high school mathematics educators face in contextualising their teaching?

METHODOLOGY

Ethnographic and survey research designs were employed in this study. The data were gathered through observations, interviews with the builders and questionnaire for the educators. The total population of the builder was sixty-eight from all six municipalities. Given the vastness of the target
population within Limpopo Province, accessibility and convenience, a sample size of six builders, one from each of the six chosen municipalities was selected and participated in the study. The builders with expertise in building the traditional houses were selected from each cultural group to accommodate their cultural diversity. Lastly a self-completion questionnaire about mathematical concepts on the traditional buildings was administered to 18 Grade 12 mathematics educators, three from each of the above-mentioned municipalities, was chosen for the study. Descriptive statistical analysis and inductive analysis were used as analytic framework.

RESULTS

Preliminary results suggest that, the foundation for all traditional circular buildings were circular in shape. The area of the foundation could be calculated using the appropriate formulae. Teachers could use the foundation of the huts in teaching circumference, area, radius and diameter of a circle. Therefore, these foundations could be used to solve problems associated with the tangent, secant, cosine and sine rule, and area rule. The foundation could be used to teach activities associated with circle geometry. It was noticed that the base and the upper shape of the wall was circular in shape but the building itself was cylindrical in shape. The shape of the wall could also be used to solve problems associated with cylinders and spherical structures. It goes without saying that cultural artefacts such as buildings could be used as examples from the learners' immediate environment to teach mathematics in context.

RECOMMENDATIONS

Based on the above findings, for the meaningful teaching and learning of mathematics to take place, the following recommendations are proposed, The role of IKS need to be emphasised in the syllabus, contextualized materials also need to be developed and used in the presentation and assessment of the mathematics lessons. Teacher training programmes need to include sections that focus on culture, society, the relationship between mathematics and culture, and the history of evolution of mathematical concepts.

REFERENCES


THE ROLE OF TEACHING AND LEARNING THEORIES IN THE TEACHING OF SCIENCE AND MATHEMATICS AT HIGH SCHOOL: A Case of In Service Postgraduate Science and Mathematics Students

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Introduction

The integration of self-regulation in the teaching of science and mathematics is crucial. The lack of regulation in the teaching and learning of mathematics and science at high school is evident when learners find the subjects difficult to understand. The department of education initiated different teachers’ development programme aimed at improving teachers’ content knowledge and teaching skills in the STEM subjects (Sibanda & Jawahar, 2012; Bansilal, Goba, Webb, James & Khuzwayo, 2012). Adequate research has focus of teachers’ pedagogical content knowledge; how to improve the teaching and learning of mathematics and science in schools, but limited studies have focused on self-regulation in teaching and learning of science and mathematics (Dobber, et al (2017). We believe that teaching these subjects through regulation might improve the quality of learning of mathematics and science in schools. According to Dobber, et al (2017) ‘teachers employ metacognitive regulation to teach students how to think and act as scientist’ (p. 204). Some researchers have emphasized the importance of self-regulation on promoting thinking skills, promoting the culture of inquiry, and nature of science (Ben-David & Zohar, 2009; Smithenry, 2010), teacher based meta-cognitive scaffolding in teaching computers (Wu & Perdersen, 2011; Kyza, 2009), conceptual regulation (Kock et al, 2013) and social regulation (Apedoe, Ellesfoson & Schunn, 2012).

Theoretical framework

There are several theories of learning, for example behaviourist view learning as an interface between personal, environmental and behavioural factors. These factors have a direct influence on the other two. These factors lead to the development of self-regulated theories, which claim that learning is regulated by an interaction between cognitive, metacognitive and motivational aspects (Zimmerman, 2000). Cognition refers to skills that are necessary to encode, memorise and recall information. Metacognition focus on skills that enable learners to monitor their cognitive processes. Motivation refers to beliefs, attitudes and these factors influence the development of cognition and metacognition (Zimmerman, 2000).

Aim of the study
The purpose of this study is to understand the nature of self-regulation practices used by mathematics and science teachers at high schools. The overarching questions guiding this investigation are:

1. What teaching and learning theories do teacher use in their teaching of mathematics and science at high school?
2. Why do teachers use a particular theory in their teaching of mathematics and science at high school?

Methodology

The study is located within interpretive paradigm and employs a qualitative approach to data collection (Creswell, 2014).

There were 60 students enrolled in the honors science and mathematics module and only 40 participated in the study. The students were asked to complete questionnaire with open-ended questions. Data was analyzed using Excel. There are 20 males and 20 females. Most of the participants were novice teachers with a teaching experience of between 0 to 5 years (28), 6 to 20 years (6) and more than 11 years (6).

Results

The results were analyses using Excel. Themes that emerged from the teachers’ comments were colour coded.

<table>
<thead>
<tr>
<th>Preferred theory</th>
<th>Number of teachers</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behaviourist</td>
<td>14</td>
<td>35.0</td>
</tr>
<tr>
<td>Constructivist</td>
<td>12</td>
<td>30.0</td>
</tr>
<tr>
<td>Cognitivist/ metacognition</td>
<td>11</td>
<td>27.5</td>
</tr>
<tr>
<td>Argumentation and reasoning</td>
<td>3</td>
<td>7.5</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>100.0</td>
</tr>
</tbody>
</table>

The results show that behaviorist (14), constructivism (12) and cognitivist/ metacognition were commonly used teaching and learning theories in high schools. It was interesting to note that three teachers indicated using argumentation as well as reasoning to teach science and mathematics in schools.

What is surprising is that the teachers who indicated that they taught mostly from a behaviorist perspective show some confusion about this theory. The following quote illustrate what the teachers said about teaching from the behaviorist perspective:
If a learner knows there is a stimulus for example a reward or a punishment they tend to focus and control their behaviour, thus this theory is useful in teaching maths as learners know if they do well, they have chances to better their lives in future i.e. going to varsity, job opportunities but I integrate it with cognitivism (Participant-3)

In the quotes, the participant focus is on the behavior of learners and they ignored the other two components of the behaviorism, which include the environment and personal issues.

<table>
<thead>
<tr>
<th>Reasons for using a particular theory</th>
<th>Number of teachers</th>
<th>Percentage of teachers (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good reward promotes good behaviour and achievement</td>
<td>12</td>
<td>30.0</td>
</tr>
<tr>
<td>Assist learners to construct their knowledge and learn from each other</td>
<td>12</td>
<td>30.0</td>
</tr>
<tr>
<td>Learners are able to argue and become critical and independent</td>
<td>8</td>
<td>20.0</td>
</tr>
<tr>
<td>Assist learners to engage in problem solving</td>
<td>7</td>
<td>17.5</td>
</tr>
<tr>
<td>No response</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>100.0</td>
</tr>
</tbody>
</table>

The results show that the teachers in the current study teach from a particular theoretical perspective. It is surprising that a few (17.5%) teachers prioritise problem solving.

Discussion

The findings show that most teachers use behaviorist theory, this is surprising because the constructivist approach is the one advocated by the department of education (Department of education, 2011). Following teachers’ explanations as to why they use behaviorist theory, it is established that pressure brought by examinations particularly in the National Senior Certificate compel teachers to drill learners in order to do well in the examinations.

Conclusion

In this short paper, we have presented teachers’ preferences of the teaching and learning theories and their explanations why they use specific theory. In the bigger study, we further present responses from the interviews of the selected participants.

References


In a fast-changing world where technology and globalization is shaping the way we do things, teachers need to adjust and think differently about the way they teach. Mathematics classes need to become more creative and teachers must be creativity innovators (Kereluik, Mishra, Fahnoe, & Terry, 2013). However, in the traditional classroom in South Africa, teaching mathematics is still rigid (Khembo, 2011). Creativity is seen one of the most important skills required for success in the 21st century. Therefore teachers will have become creative and innovative when applying their knowledge and skills to teach learners to face the complex challenges of the 21st century (Kereluik et al., 2013). For this reason, it is imperative that Art should be included in STEM (Science, Technology, Engineering and Mathematics) to prepare our learners to meet the next century challenges.

In STEAM, art is included in the STEM mix as a new educational model. The movement from STEM to STEAM is a more recent development although the idea of incorporating creativity into science and technology has been used, thought about and written about for many centuries (Steyn & Buys, 2011). Many schools are now moving towards including creativity in their teaching and learning to assist their learners with STEM (Bazler & Van Sickle, 2017). STEAM as an educational approach is becoming increasingly popular in the USA (Catterall, 2017; Maslyk, 2016), China (Catterall, 2017), Korea (Kim & Bolger, 2017), Finland (Havinga & Portaankorva-Koivisto, 2016) and the UK, since educators have recognised the need, for adding creativity to the STEM subjects. However, in South Africa, the STEAM approach has not been adopted and the traditional methods of teacher-centred teaching are still prevalent in most classrooms (Wolhuter, 2014). To include art and a more interdisciplinary setting in a mathematics classroom will necessitate a change in the teachers’ perceptions about teaching mathematics.

The advantages of STEAM are widely accepted for a number of reasons (Madden et al., 2013). Firstly, by using learning strategies that include art, creativity and design methods, learners may be included that have lost interest due to the more traditional teaching methods (Catchen, 2013). Secondly, it also makes the subjects more relevant to the real-world (Catchen, 2013). Thirdly, the inclusion of art into STEM strives to introduce learners to creativity and a wider variety of knowledge and skills that are important in preparing them for a work environment that is changing due to technological advances (Bazler & Van Sickle, 2017). Fourth, the components that are used extensively in the STEAM approach such as the use of models, manipulatives and cultural artefacts is considered “a significant component of powerful learning environments” (Vosniadou & Vamvakoussi, 2006). Although STEAM
seems like a good idea many good ideas have failed in the past if they were not conveyed to the teachers effectively during professional development. It is thus of great importance to also determine the most effective method of teacher professional development for the specific group of teachers being studied (Clarke & Hollingsworth, 2002; Goldsmith, Doerr, & Lewis, 2014; Guskey, 2002). The aim of the study is to introduce teachers to including art and creativity in the mathematics classroom through professional development and to determine how their perceptions of teaching mathematics change.

The question guiding the proposed study is:

   How does the perception of mathematics teachers change after they have been introduced to the STEAM model for teaching mathematics?

Then these are the sub-questions:

   What are the teachers’ implicit perceptions of teaching of mathematics?
   What are the teachers’ implicit perceptions of including STEAM in the teaching of mathematics?
   How did the teachers’ perceptions of teaching mathematics change after a professional development programme based on the STEAM approach?

In the proposed qualitative, exploratory, case study a professional development programme based on the model of teacher change by Guskey (2002) and informed by the results of initial surveys will be used to introduce the STEAM approach to a group of GET mathematics teachers in the Nelson Mandela Bay Area. An initial survey will be conducted amongst a much bigger sample population of 80 Eastern Cape schools linked to the GMMDC (Govan Mbeki Mathematics Development Centre). This survey will be designed to determine the perceptions of the mathematics teachers about teaching mathematics, their perceptions of including art in the STEM model and their perceptions of effective professional development. The results of the survey will be used to compare with the results of the survey data collected during the professional development course. The proposed time for the professional development will take place over the course of one year. During this time the data on the teachers’ perceptions will be also collected during focus groups, observations and interviews and compared with the results of the surveys.

Worldwide there is a shortage of people following the STEM careers (Powers, 2017). However, by using the STEAM model to change mathematics teachers’ perceptions and encouraging creativity in the classroom, it is hoped that more learners will be encouraged to pursue STEM careers. The development of an effective professional development course using STEAM is essential as it could be used in future programs and in due course it could also have an influence on the policy makers.

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AN ANALYSIS OF PRIMARY STUDENTS’ CALCULATION STRATEGIES FOR ADDITION AND SUBTRACTION IN ZAMBIA
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Abstract
This paper reports the findings of an analysis of students’ calculation strategies. Prior surveys and research have pointed to students’ low achievement in numeracy, but precisely how students calculate and the kinds of strategies they use have not been discussed. Therefore, the present research was conducted at a primary school in Zambia focusing on students’ calculation strategies. The study found that students select specific strategies and material based on the situation. For addition, they prefer the Counting-on strategy using their fingers, whereas they prefer the Counting-all strategy using concrete material or drawing sticks for subtraction. These results provide an opportunity to improve students’ understanding of calculation.

Introduction
World Bank (2018) has drawn attention to a current “learning crisis,” emphasizing the importance of education on a global level. Working on the qualitative improvement of education in many developing countries is now considered an urgent task. Focusing on Zambia, SACMEQ (2011) showed that only approximately 8% of students who took assessment reached the minimum required level of mathematical ability. EGMA (RTI International, 2009) and a National Assessment Survey (RTI International, 2015) of second-grade students revealed that there are many children who cannot solve simple additions and subtractions. After these findings, the Zambian government emphasized the importance of numeracy in primary education (Ministry of National Development Planning, 2017).

In prior research on mathematics education in Zambia, Uchida (2012) clarified that the learning outcome included students understanding calculations superficially, operating mechanically, and relying on sticks for addition.

Although previous studies and surveys show that students’ calculation achievement is severely low, the data does not clarify how students can and cannot calculate. There is an absence of qualitative data on students’ actual calculation strategies. Without fully grasping the details of children’s learning situations, it is difficult to solve the current learning crisis.

Research Objective
The study’s purpose is to clarify students’ calculation strategies, especially when it comes to addition and subtraction. The study’s research questions are as follows:
1. How do students calculate addition and subtraction?
2. What kinds of strategies do students use for calculation?

**Literature Review**

Researching children's addition strategies, Yuzawa and Hino (2017) showed the progression of an addition strategy as follows:

- **CA:** "counting all": Start counting from 1 and count everything.
- **CF:** "contiguous folding": Put out fingers for the augend and take out the addend from the continuation. Thereafter, there are times when you count from the beginning or answer using a finger.
- **CO:** "counting on": Start counting from the next number of an augend.
- **TEN:** "use the composition of 10" (make 10): Calculate by making 10 by synthetic decomposition or adjustment of two numbers.

Although there are differences among children, the study states that children's additive strategy generally develops in the order of CA, CF, CO, TEN.

Investigating subtractive strategies, Sakakibara (2014) shows two strategies:

- **CU:** “Count-up strategy”: Count how many steps are taken from decreasing to minuend.
- **CD:** “Count-down strategy”: Count steps down from the minuend by the decrement.

The above strategies feature the use of fingers; no other strategy using concrete materials has been mentioned in prior research. This is because there are few opportunities to examine actual situations where concrete materials are used in mathematics education. Another possible strategy is to recall the answer from memory, especially for CA in subtraction (which counts everything).

**Conceptual Framework**

Based on previous research, each calculation has five stages (see Table 1). Table 1 includes “Counting-unit,” meaning that students can count based on the idea of numerical units.

<table>
<thead>
<tr>
<th>Addition</th>
<th>Subtraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Counting-all (CA)</td>
<td>Counting-all (CA)</td>
</tr>
<tr>
<td>2 Contiguous folding (CF)</td>
<td>Counting-up (CU)</td>
</tr>
<tr>
<td>3 Counting-on (CO)</td>
<td>Counting-down (CD)</td>
</tr>
<tr>
<td>4 Counting-unit (UNIT)</td>
<td>Counting-unit (UNIT)</td>
</tr>
<tr>
<td>5 Mental counting or Memory (MM)</td>
<td>Mental counting or Memory (MM)</td>
</tr>
</tbody>
</table>
Students tend to combine these strategies with tools like fingers, drawing sticks, and concrete materials. For the study's survey, students were free to use any materials for calculation. Considering that many children in Zambia have linguistic difficulties, an observational approach was used in this survey.

**Methodology**

*Data collection*

The subjects to be surveyed included five children (A, B, C, D, E) from the 3rd grade and seven from the 5th grade (F, G, H, I, J, K, L) in the southern province of Zambia. The survey was conducted on June 6 and 7, 2017. Each student was called to the school library individually, where the observation survey was carried out.

These seven questions were given to the students as calculation problems in the observation survey, but in this paper, researcher focus on these three problems: ① 19-4, ② 5+4, ③ 10-3. Videos were recorded to examine how students calculated the problems and to analyze their behavior. The researcher placed bottle caps, an egg tray, blank paper, and question paper on the desk for the students.

**Findings**

Students’ performance revealed that they calculated the problems using certain strategies, which are clarified below.

For solving “19 - 4”, six students (C, E, F, G, H, L) switched materials and strategies. Student C tried to draw sticks but then switched to bottle caps and used CA. After that, to confirm the answer, he applied CO with the use of fingers for "15 + 4." Student E tried to use his fingers, but switched his strategy to drawing sticks after reading "nineteen." After starting to draw sticks, he switched again to bottle caps. Student H tried separating his fingers and counting them but soon changed to drawing sticks.

In the case of "5 + 4", two students (C, D) changed their materials and strategies. Student C chose the Count-on strategy using fingers at first, but then switched to CA with stick-drawing, and then back to CO with fingers.

In the case of "10 – 3", four students (D, G, K, L) switched materials and strategies. Student G said “it seems 7” and then counted “eight, nine, ten” using CO with fingers. Student L used the Count-all strategy using sticks, but then compared the answer with the problem and recalculated using CA again.
Based on students’ strategies, researcher identify students’ tendency as follow.

1. **Differences between addition and subtraction**
   For addition, students preferred CO to CA. For subtraction, most students used CA. Additionally, students switched materials depending on their strategies. When using CA, they chose drawing sticks or bottle caps. When using CO and CU, they preferred to use their fingers.

2. **Changing strategies within a problem**
   The above discussion shows examples of changes in strategy for various problems. Overall, there were two purposes for changing strategy and/or materials.

   2.1. **To confirm the answer**
   Despite having already answered, students confirmed their answers with another strategy. Particularly with subtraction tasks, students used CU to confirm their answers using addition. Moreover, if students checked their answers and then felt “uncomfortable” or lacked confidence, they recalculated using a more suitable strategy. This reveals that students have a kind of meta-cognition. They can evaluate the situation as well as their own strategies or answers.

   2.2. **To rationalize the operation**
   A few students tried to draw sticks, but they stopped and switched to using bottle caps. This suggests that drawing is hard for students, or that they feel that bottle caps are easier to operate. Students do not use strategies where they lack confidence, and they typically have one strategy that they can use confidently at any time. However, students will use an easier or faster strategy if it will reduce the time or difficulty required to solve a problem.

**Conclusion**

This research revealed that most students rely on CA and CO with the use of materials. Additionally, students possess a number of strategies and tend to choose the best one depending on the specific situation and conditions. The present study confirms the idea that students are familiar with a number of calculation strategies and that teachers should fully grasp students’ learning and understanding processes.

**References**


PROBLEM SOLVING MODEL DEVELOPED BY PRE-SERVICE MATHEMATICS TEACHERS
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ABSTRACT
The main aim of the study was to investigate the problem-solving models used by 50 pre-service mathematics teachers. The pre-service teachers were divided into 10 groups of 5 and then asked to solve three non-routine mathematical problems, one problem per week for three weeks. The groups were encouraged to write all the steps they used in solving each problem. They were observed as they solved the problems by two of the researchers. The study used document analysis in the form of written responses from pre-service teachers. Their solutions to the problems were analysed in relation to George Polya’s problem solving model.

The pre-service teachers’ responses revealed the models they used to solve the problems. The steps used by pre-service teachers in solving the problems turned out to be the generic problem-solving models. Pre-service teachers’ use of a model in the problem-solving process enabled them to achieve deeper levels of understanding in order to adequately describe the solution process.
THE ROLE OF VIDEO IN THE DEVELOPMENT OF PRESERVICE TEACHERS
MATHEMATICS LESSON PLANNING

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ABSTRACT
This paper emerges out of an intervention that seeks to develop pre-service teachers’ (PST) reflective competence. Many PSTs struggle to reflect on their lessons during Teaching Practice. Reflection is often superficial and focuses primarily on aspects related to classroom management (e.g. discipline) rather than the mathematics content. The intervention drew on the VIDEO-LM project of Karsenty (2018). PSTs observe videos of mathematics lessons, which they reflect on in groups. Drawing on data from three sources, the lecturer, a PhD student and an assessor of the students’ work, VIDEO-LM project has been successful as a tool for lesson planning.

Introduction and Literature Review

Karsenty (2018) noted three regular uses of video in teacher education: to expose teachers to new pedagogical strategies; as a source for feedback on teachers’ classroom practices; and to enable discussion of learners’ mathematical thinking. A fourth use developed by Karsenty, Arcavi and Nurick (2015), through their VIDEO-LM Project (Viewing, Investigating and Discussing Environments of Learning Mathematics) is the development of reflective competence and Mathematics Knowledge for Teaching (MKfT).

Nemirovsky and Galvis (2004) state that “because of the unique power of video to convey the complexity and atmosphere of human interactions, video case studies provide powerful opportunities for deep reflection” (p.68). Reflection is a necessary skill to becoming an effective teacher. Karsenty et al. (2015) developed a tool, referred to as Six Lens Framework (SLF), to guide teachers in analysing, and reflecting on, the teaching of mathematics.

The Six Lens Framework
The six lenses were developed “to emphasize their use as a means of observation, in the dual sense of watching an occurrence but also commenting on it. Viewing a lesson through a certain lens implies shedding light on a specific feature of the mathematics teaching practice” (Karsenty et al., 2015) p.272). The six lenses are:
In this research SLF was used to direct the PSTs’ attention to important aspects of a mathematics lesson.

**Methodology**

The research is an interventionist case study. The aim is to develop preservice teachers’ reflective competence, by watching videos of Foundation Phase teachers teaching mathematics. The data for this paper is from three sources and appears in the form of narratives. AAAA, is the third year B.Ed lecturer who is using VIDEO-LM in the mathematics methodology lectures. BBBB, is a PhD student researching the use of VIDEO-LM in the development of PST reflective competence. CCCC is the assessor of the lesson planning assignment. The assignment required them to develop a lesson plan for grade 2 learners on subtraction of two 2-digit numbers using the SLF. These narratives have emerged from the journal notes of the first two authors and written feedback on lesson plans from the third author.

**Three stories**

The following narratives have been edited for readability.

**BBBB’s story**

*The progress to date has been slow and students have taken a long time to understand the lenses. Three lectures were allocated to these VIDEO-LM sessions. My research data takes the form of individual reflections, group reflections, and plenary discussions with the students. There have been challenges: lectures are too short to watch the entire video as well as reflect individually, in groups and as a class. The students have taken a long time to understand the different lenses. AAAA has chosen to focus on one lens at a time with the entire class. As the lectures progressed, the class discussion on each lens deepened and it appeared that the PSTs had come to an understanding of what it means to reflect and how they can do so using the SLF.*
The problem with the introduction of the lenses is that the PSTs found it difficult to differentiate between the goals of the lessons and mathematical and meta-mathematical ideas. We suggest that a better way to differentiate between these two may be to replace the latter with ‘topic and process skills’ as this will ensure that this is not conflated with the goals.

AAAA’s story

Having visited students on teaching practice, I knew that they battled to reflect on their lessons. Comments at the end of their lesson plan, particularly during their 1st teaching practice were superficial and had little to do with the content they were teaching. The SLF, provided an opportunity for me to develop the students’ reflective competence by drawing their attention to specific aspects of the lesson. The introduction to the lenses has taken longer than I initially thought. The students battled to grasp the meaning of each of the lenses, and to use them to reflect on the videos of lessons I chose. I have had to scaffold the process by focusing on one lens at a time as a whole class rather than in groups. I realised that the students were battling to describe the lessons, let alone analyse them, so I spent time getting them to describe the lesson. While working with the students, I realised that there may be potential to develop their lesson planning skills using the SLF. We did this exercise in class and the students were really engaged in the activity. In addition, during their teaching practice preparation workshop, we used the SLF to brainstorm the various aspects of a lesson on addition of two 2-digit numbers, which they then used to develop a coherent lesson plan. It seems that this process of planning a lesson has helped to ‘cement’ the SLF and now, finally, I feel that I can start using it as a tool for reflection.

The problem with the introduction of the SLF as a reflective tool, is that we missed an important and necessary precursor to reflecting on practice. This is the process of describing what is occurring in the lesson, particularly in relation to the teaching of mathematics. We realised that describing a lesson is a necessary pre-cursor to reflecting on the lesson. This practice also enables the PST to focus on the mathematics rather than issues of classroom management.

CCCCC’s story

My expectation was to receive work that was largely superficial in its description of how the lesson would progress and lacking somewhat in insight as to the mathematical dilemmas that may occur.

The work that these students produced represented a real breakthrough in understanding around these issues in particular. The majority of the lesson plans included careful consideration of the interactions between learners and between the teacher and learners around the mathematical content of the lesson. The lessons were also described with more mathematical detail than I had expected. In descriptions of the anticipated dilemmas, approximately half of the class remained focused on classroom management exclusively, but the remainder focused either only on mathematical content or on a blend of the two.

My experience has been that students at this stage of their development as mathematics
teachers are unable to comment beyond statements such as ‘some learners may struggle with the mathematics’. There were now students who were able to make comments such as ‘some learners may not understand place value’, or ‘some learners may not know how to break down numbers’. Their identification of the requisite prior knowledge was also more nuanced than simply, e.g. ‘learners know how to add’.

Discussion and conclusion

The introduction of the VIDEO-LM intervention and the SLF as a reflective tool with PSTs has been slow and the students have grappled with the lenses. They have had minimal teaching experience and have thus found it difficult to understand why the teacher is doing what she is doing. Shifting the focus to lesson planning seems to have been worthwhile as the students are required to focus explicitly on the mathematics that is being taught rather than general classroom management. We are encouraged by the progress we have seen in their lesson planning. Using the SLF to brainstorm the lesson and/or guide the planning of their lesson seems to be beneficial. From the initial brainstorming of ideas related to each of the lenses, the PST have been able to pull the ideas coherently into the formal lesson plan template. We’re looking forward to seeing their progress as they gain more classroom experience. The time seems right to shift them from using the SLF for lesson planning to reflecting on teachers’ mathematics teaching.

References

“FAILING LIKE FLIES”: Dispelling Deficit Perceptions of Engineering Students Through the Inclusion of a Humanising Vocational Pedagogy in a Short Course for TVET Maths Lecturers.
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Maths Lecturer: “These students are weak, they need structured lessons and practice otherwise they fail like flies. After so many years we know how to teach and they must just follow the method. Simple as that. There is no time for doing things outside the textbook. And in any case showing the students another way would just confuse them.”

Later in the afternoon maths clinic when I was required to engage with the students one TVET student shared:

TVET Student: “We are used to this. Our teacher does not want us to ask her any questions even when we are writing a test. She penalises us for using our own methods. She only wants us to do things her way.”

Reflecting on this scenario and the feedback received from both the TVET lecturer and the student the learning space seems to be inflexible and not conducive or enabling for students to demonstrate their own understandings. In reviewing the teacher’s words, “weak”, “fail like flies”, it appears as though a deficit view of the student pervades hence, the kind of pedagogy subscribed to, is based on “structured methods and practice.”

“Writing the world with mathematics means to use mathematics to change the world.”
(Gutstein, 2006, p. 27)

Grounding mathematics instruction in students’ languages, cultures, and communities, while providing them with the knowledge needed to survive and thrive in a dominant culture enables the development of positive cultural and social identities. Gutstein (2006, p.23) in his book “Reading and Writing the World with Mathematics: Towards a Pedagogy for Social Justice” advocates for mathematical pedagogical goals as “reading the mathematical word, succeeding academically in the traditional sense, and changing students’ and teachers’ orientation to mathematics.” According to Gutstein (2006, p.23), reading the mathematical word means developing mathematical power, defined as deducing mathematical generalisations, constructing creative solution methods to non-routine problems, and perceiving mathematics as a tool for socio-political change. Succeeding academically in the traditional sense means to have students achieve on standardised tests, graduate from high school, succeed in college, have access to advanced mathematics courses, and pursue mathematics-related careers (if they choose to do so), and changing students’ and teachers’ orientations to mathematics means to understand mathematics not as a series of disconnected, rote rules to memorise and regurgitate, but as a powerful and relevant analytical tool for understanding complicated, real-world phenomena.
Building on the work of Gustein (2003, 2006), Skovmose (2005) and more recently Wager and Stinson (2012) provide contextual considerations for appropriate mathematics pedagogy for the marginalised. My research is relevant since learner performance in the Trends in International Mathematics and Science Study (TIMSS) study places South Africa amongst the lowest five countries (Ngoepe, 2016). The TIMSS results further indicate that the Western Cape, Gauteng, and Mpumalanga are the best-performing provinces while North West Province, Limpopo, and the Eastern Cape were the worst performing. In other words, achievements in maths and science continue to remain highly unequal with only one-quarter of children at public, no-fee schools (Quintile 1, 2 and 3) getting mathematics scores above the minimum level of competency (Reddy, 2016 as cited by Ngoepe, 2016). Hence, a socially just and humanising approach to mathematics education, is an appropriate for the post-conflict South African context. Research by Graven (2013) confirms that mathematics education in South Africa operates in ways that leave a significant proportion of marginalised students with negative mathematics experiences and inadequate mathematical preparation. The challenges are both historical and systemic, and the students most disaffected by the current system are overwhelmingly black or first-generation tertiary education students.

An indicator of this reality is reflected in who drops out of school and which part of the population accesses TVET colleges. Table 1 shows the number of students enrolled at TVET colleges by qualification and race. From data it is clear that the vast majority of students enrolled at TVET colleges are Black Africans children who are likely to be marginalised suffering from poverty and poor socio-economic conditions.

<table>
<thead>
<tr>
<th>Qualification Category</th>
<th>African</th>
<th>Coloured</th>
<th>Indian/Asian</th>
<th>White</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>NATED (N1-N6)</td>
<td>479 160</td>
<td>27 920</td>
<td>2 080</td>
<td>7 899</td>
<td>262</td>
</tr>
<tr>
<td>Report 550/NSC</td>
<td>895</td>
<td>88</td>
<td>5</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>NC(V)</td>
<td>156 429</td>
<td>7 597</td>
<td>263</td>
<td>606</td>
<td>44</td>
</tr>
<tr>
<td>Occupational Qualification</td>
<td>13 935</td>
<td>4 016</td>
<td>269</td>
<td>1 483</td>
<td>56</td>
</tr>
<tr>
<td>Total</td>
<td>650 419</td>
<td>39 621</td>
<td>2 617</td>
<td>9 996</td>
<td>362</td>
</tr>
</tbody>
</table>

The Engineering programmes at TVET colleges are amongst those in the highest demand. However the throughput rate is low. Data from 2015 examinations in NC(V) L4 engineering courses shows that only 25% of those who wrote passed (DHET, p. 10). The reason for the low throughput rate has been linked to a high failure rate in the maths courses in the programmes. One of the concerns has been that direct teacher-centred instruction with an emphasis on the practice of abstract problem solving due to a rigid mathematics curriculum. Since TVET programmes however require a much more applied and practice-based approach to the teaching of mathematics it is contended that a different pedagogy (a vocational pedagogy) should be explored in order to develop mathematics skills that inform Engineering practice. Hence, the main research question explored in this paper is whether the
inclusion of a humanising vocational pedagogy could transform the teaching of mathematics in engineering related subjects at TVET colleges.

Hence the main contribution of this study is to explore how a humanising approach transforms the vocational pedagogy of maths teaching in engineering related subjects in TVET classrooms especially in the development of functional and mathematical literacies that disrupt the current dominant social relations towards the enhancement of “life” success for students. In this way this study seeks to challenge the framing of the teaching of mathematics from the perspective of economic competition to a social justice agenda that places the material, social, psychological, spiritual, and emotional needs of human beings (the TVET student), before capitalistic needs. A critical theoretical framework housed in a humanising pedagogy is deemed appropriate for this study.

A humanising pedagogy is not a one-size-fits-all pedagogy, but one that values students’ and teachers’ background knowledge, culture and lived experience (Bartolomè, 1996), moving students and teachers into their own ever-expanding interpretations of their lived worlds (Green, 1996). A humanising pedagogy supports a problem-posing pedagogy in which subjects who know and act, in contract to objects which are known and acted upon. Freire (2000, p.83) writes that students “develop their power to perceive critically the way they exist in the world with which and in which they find themselves.”

A problem posing pedagogy is dialogical where the “teacher is no longer merely the one who teaches but one who is taught in dialogue with students who in turn while being taught also teach” (Freire, 2000, p.80). The dialogical educator creates pedagogical spaces for epistemological curiosity where students (and teachers) become apprentices in the rigors of exploration (Freire & Macedo, 1996). These epistemologically curious spaces refuse singular explanations that attempt to provide a locus of certainty and certification around the constructs of race, gender, ethnicity, class and sexual orientation (Lewis & Simon, 1996). Through epistemological curiosity teachers and students develop a critical ontology that assists them in understanding and why they have been shaped by power relations and ideology of dominant groups (Kincheloe, 2003). Above all, a humanising pedagogy links the classroom experience to the wider socio-political community recognising schools (and TVET colleges) as public spheres where teachers and students engage in a process of deliberation and discussion aimed at recapturing the idea of critical democracy and community (Giroux & McLaren, 1996).

While there is limited research on how the discipline of mathematics is positioned within a humanising pedagogy, it too is growing (for example, Bartell, 2011; Gonzales, 2009; Gutstein & Peterson, 2005; Gutstein, 2003, 2006 & Skovsmose, 2005). Hence the contribution of this study adds to the existing body of knowledge by exploring a South Africa, TVET college mathematics perspective.

As part of the research methodology for this study, a short course on a humanising pedagogy will be designed as part of continuous professional development of 10 TVET maths lecturers, since “one of
the most often-argued critiques is how do teachers learn to teach mathematics in socially just and humanising ways?” Bartell (2011) contents that within the mathematics education literature there are a few accounts of how teacher education programmes and/or professional development opportunities might engage pre-service and in-service teachers in pedagogical skills that serve a humanising classroom. In this paper, I share with critical friends the design of the short course and the content and participatory methodologies to be used with participants.

Through sharing and deliberating over content, process and praxis, it is hoped that the short course can be refined and further developed before data gathering begins.

REFERENCES


Abstract
Maths teaching and learning at South African Universities is a continuation of poor secondary school practices and the demand for extra tuition in Maths than any other subject is growing fast. The point of departure for any discussion about Maths problems is to recognise the distinctive nature of Maths as a subject. Maths is a developed skill, learned progressively by a slow and steady acquisition of concepts, and by building operational and problem-solving skills.

One way to overcome the several challenges in learning maths has been to create a Maths Centre where mostly engineering and applied sciences students visit to be tutored. The creation and sustenance of a Math Centre at University of Technology has resulted in the increasing of both the pass rate and success rate amongst students. The Maths Centre has brought a more convenient and efficient platform for after-class remediation help to students. This has been done through the one-on-one interactions between students and tutors which give the learner a leading role and a complete active involvement for the guidance requested.

The aim of the centre is to provide non-judgemental support to students outside their normal teaching time. Studies show that Mathematics Tutoring Centres can be viewed as one of the examples of new programs and services to improve students’ chances of success in colleges and universities (Jaafar, Toce & Polnariev 2016). Mathematics support generally takes the form of Mathematics Support Centres (MSC), whose main aims are “to address issues surrounding the transition to university mathematics and to support students’ learning of mathematics and statistics across the wide variety of undergraduate courses that require an understanding of mathematical concepts and techniques” (Matthews, Croft, Lawson & Waller 2012). Our aims of the centre were also supported by the works of Lawson (2012) which cite that “the key purpose of mathematics support centres is to assist students to achieve full potential”.

The services which the maths centre is currently providing to students include:
• One-on-one consultations
• Small group consultations (2 to 5 students per session)
• Tutorial classes (one hour per week per class)
• Diagnostic testing (only first-year Maths students)
• Extra classes / exam revision sessions (in preparation for tests or exams).
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• Diagnostic testing (only first-year Maths students)
• Extra classes / exam revision sessions (in preparation for tests or exams).

What have been the highlights and success and likewise the challenges of such a centre? This paper brings together three years of research to analyse and promote the use of the maths centre at a University of Technology.

Keywords: maths centre, challenges, maths, pass rate, success rate.

References

USING CONCEPT MAP CONSTRUCTION AS A PROFESSIONAL DEVELOPMENT ACTIVITY AIMED AT DEVELOPING A TEACHER’S CONTENT KNOWLEDGE FOR TEACHING A BIOLOGY TOPIC: A SELF-STUDY

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ABSTRACT

Many professional development activities for teachers take the form of workshops, conferences or degree programs in which opportunities for improvement are provided as a one size fits all. While these activities can improve teachers’ content knowledge or pedagogical knowledge, they do not cater for individual teachers’ needs. As a response to this ‘one-size fits all’ situation, this study investigated the effectiveness of concept map construction as a professional development activity aimed at developing an individual teacher’s content knowledge of a biology topic using the methodology of self-study. The methodology of self-study was chosen as it offers opportunities for an individual to study their own practice for purposes of improving specific aspects of one’s practice in this context-content knowledge of meiosis. The data that was collected consisted of concept maps and journal entries. Three concept maps were constructed and analysed with input from a critical friend and content expert. Journal entries consisted of my reflections on the feedback I got from and the discussions I had with the critical friend. Findings from this study showed that the use of concept map construction by an individual teacher in the context of a self-study can reveal the teacher’s content knowledge gaps and misconceptions about the topic under study. The study therefore concluded that constructing concept maps as a professional development activity to represent one’s content knowledge has the potential to expose the builder’s level of understanding of a biology topic and to provide opportunities for correction and improvement of one’s content knowledge. Through the use of the methodology of self-study and working with a content expert as a critical friend, individual teachers can successfully engage in professional development for purposes of improving their content knowledge of biology one topic at a time.
PRE-SERVICE TEACHERS’ CONCEPTUALISATION OF THE INTEGRATION AND PROGRESSION OF LIFE SCIENCES CONCEPTS FROM GRADE 10 TO 12

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ABSTRACT
When scientific concepts are learned as discrete science concepts learners fail to know how the concepts are related to each other. Learner conceptual understanding is enhanced when teachers develop a sense of continuity and coherency in learners as they teach one topic to another. After realising that pre-service teachers compartmentalise concepts and fail to show relationships between concepts as evidenced from their failure to teach the concepts accordingly, the researcher tasked 115 pre-service Life Sciences teachers to conceptualise and articulate the integration and progression of Life Sciences concepts from Grade 10-12 in groups of six. The study investigated how pre-service teachers articulated the way they conceptualised this integration and progression. Thematic analysis of the responses, from the 10 groups who selected the topic Cells, showed that pre-service teachers could articulate the integration and progression of concepts from Grade 10 - 12 to a certain extent. It was evident that they needed to acquire a deeper understanding of Life Sciences concepts in order to explicitly interconnect them. The study informs teacher professional development programmes of strategies that engage teachers in activities that stimulate them to identify areas for development.

Key words: Integration, progression, pre-service teachers, Life Sciences.
THE CONTENT KNOWLEDGE TEACHERS USE WHEN TEACHING THE DOPPLER EFFECT

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ABSTRACT
The poor performance in physical science in South Africa is well documented. The low pass rate has been attributed to various factors like teaching strategies, learners’ interest and motivation, teachers’ subject matter knowledge, lack of resources and media of instruction. Even though science teachers’ knowledge has been researched in the South African context there is still a need for research on topics such as Doppler Effect. Teachers’ knowledge portrayed during teaching can be described in terms of its type and qualities. Types include conceptual and procedural while qualities include level, structure and modality. This was a case study focusing on teacher teaching Doppler Effect with the focus on type and qualities on their content knowledge-in-use. The results show that the two teachers’ content knowledge was mainly in conceptual form with some aspects of procedural. The results also show that the content knowledge was mostly of deep level, coherent and represented in multiple ways that are likely to encourage learners’ conceptual understanding.

Key words: content knowledge; knowledge types; knowledge qualities
THE RELATIONSHIP BETWEEN GRADE 12 LEARNERS’ UNDERSTANDINGS ABOUT SCIENTIFIC INQUIRY AND ACHIEVEMENT IN PHYSICAL SCIENCES.

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ABSTRACT
Inquiry Based Learning (IBL) has driven curriculum reforms in science education globally, with many educators teaching science as inquiry, in the hope of improving learners’ understandings of scientific concepts and achievements in standardised tests. The curiosity of whether learners’ engagements and understandings of the Nature of Scientific Inquiry (NOSI) is capable of improving achievement in standardised Physical Sciences tests is important in validating the global emphasis on Inquiry Based Science Education (IBSE). The main aim of this study was to assess grade twelve Physical Sciences learners’ understandings about the NOSI using the Views About Scientific Inquiry (VASI) questionnaire and then compare VASI scores with achievement scores obtained from the National Senior Certificate (NSC) preparatory Physical Sciences examination, a standardised provincial test used in preparing matriculants for the final NSC grade twelve examinations. The study followed a cross-sectional survey design, and involved one hundred and seven (107) grade twelve learners from three Johannesburg high schools. Data were collected using the adopted VASI questionnaire. Responses from the VASI questionnaire were coded and scored with the aid of a rubric. VASI scores were compared against the NSC preparatory test scores using descriptive and inferential statistics. The results obtained from data analysis indicated a strong positive correlation between learners’ cumulative VASI scores and NSC preparatory scores. Group comparisons revealed no significant differences in VASI and NSC scores for male and female grade twelve Physical Sciences learners. These findings indicate that learners’ understandings about the NOSI have a positive influence on performance achievements in a standardised Physical Sciences test. The implications of these findings for practice and research are also discussed herein.

Keyword: Nature of Scientific Inquiry (NOSI), Inquiry-Based Learning (IBL), Standardised test, National Senior Certificate (NSC) examinations, VASI, Achievement.
THE MEASUREMENT OF THE IMPACT OF TEACHING ON ATTITUDES BY USE OF THE COLORADO LEARNING ATTITUDES ABOUT SCIENCE SURVEY IN PHYSICS

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ABSTRACT

Student attitudes is the extent to which students hold an expert-like belief about their approaches to physics studies (Cahill et al., 2018). In this respect, an instrument specifically designed to measure the attitudes towards physics and physics learning called the Colorado Learning Attitudes about Science Survey (CLASS) has been used for that purpose. The survey questionnaire is comprised of 42 Likert-type of questions and is used to probe students’ attitudes about physics. In particular, the focus of this research is to examine the extent to which focussed pedagogical instruction to three groups of students, namely, the Extended Engineering Metallurgy group (EXT-physics 1), the Bachelor of Engineering Technology group (BET-physics 1) and the Analytical Chemistry group (AC-physics 2), is succeeding in improving student learning and transcending their thinking towards an expert-like thinking after a semester of instruction. Results reveal that after a semester of instruction, students’ beliefs shifts towards a novice-like belief for the EXT group and an intermediate belief between novice and expert-like belief for the BET group and an expert-like belief for the AC group in the categories of beliefs mentioned above.

Key words: attitudes, beliefs, learning, pedagogical and physics
ABSTRACT

One of the challenges in the implementation of inquiry-based practical work (IBPW) is achieving an alignment of the assessment practices to the instructional strategy. The use of paper and pen examinations is prevalent as a form of assessment. Pre-service science teachers learn how to facilitate IBLW in methods courses. This paper explored the development of an alternative tool to assess how final year science teachers use topic specific pedagogical content knowledge (TSPCK) to facilitate IBPW for learners at one University in South Africa. Using a multiple case study design, data were collected by requesting 34 participants to plan a lesson that they would use to facilitate inquiry-based practical for learners. The participants organised themselves in 5 groups which constituted the cases. Each group cooperatively planned a lesson that was taught by one of the pre-service teachers to the rest of the group members. The lessons were captured on video and submitted to the researcher together with the lesson plans. The data were analysed through inductive content analysis techniques and ultimately by cross-case analysis. For IBPW facilitation two forms of content knowledge and four forms of TSPCK were identified. The identified forms of knowledge informed the recommendation of an assessment tool to measure pre-service teachers’ abilities to facilitate IBPW in science classrooms.

Keywords: Assessment; assessment tool; inquiry learning; inquiry-based practical work facilitation; physical sciences pre-service teachers
ARGUMENTATION RESEARCH IN SOUTHERN AFRICAN SCIENCE EDUCATION: HOW FAR HAVE WE COME, WHERE ARE WE AT AND WHERE TO FROM HERE?

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For close to two decades research has explored the potential for argumentation in science education and argumentation research has evolved within the curriculum change context of the region. In South Africa for instance, reference to argumentation in curriculum documentation has changed with each review cycle from overt statements about argumentation to cursory mention in the current CAPS documents (DoE 2011). The earlier link between argumentation and IKS has been lost in spite of continued curricular emphasis on inquiry and development of learner scientific communication skills. In this symposium three research groups will discuss developments in argumentation research in Southern Africa. We reflect on the following questions:

1. What argumentation research has been conducted in the region and what have we learned from its findings?
2. What forms of argumentation have emerged and how do these reflect contextual issues?
3. What is a possible research agenda for future argumentation work in Southern Africa and what are possible areas for local and international collaboration?

This presentation is compiled by argumentation research teams from UWC, CPUT and Wits.

The Critical Thinking Group in South Africa. What do we know about argumentation in science and what else can be done?

Argumentation as critical thinking stresses the evidence-based justification of knowledge claims and underpins reasoning across STEM domains. In the last decade argumentation research effort has increased dramatically (Erduran, Ozdem & Park, 2015). In 2004 the Critical Thinking Group (CTG) was established at CPUT in Cape Town. This was a community of practice comprising; educators from Western Cape schools; curriculum advisers of the Western Cape Education Department; an adviser from the national curriculum office in Pretoria; academics at CPUT, UCT and University of York in the UK. This component of the symposium will review the CTG’s research outcomes and draw on our research to identify what more might be done to advance argumentation and critical thinking for curriculum enhancement.

We raise some questions that might provide new insights and stimulate research in four key areas:
• **Teacher argumentation.** Teachers involved in developing and teaching argumentation tasks showed improved levels of argumentation according to Toulmin’s Argumentation Pattern (TAP) (Simon, 2008) and displayed features of inclusive argumentation, resolving different claims and viewpoints for consensual agreement.

To what extent can teachers (and learners) hold and use two outcomes for argumentation: one for Ubuntu-based consensual resolution of claims and another for evidence-based ‘Toulminian’ resolutions?

• **Socio-scientific and scientific contexts.** Learners showed higher levels of argumentation in a science context than in a socio-scientific one. Structuring debate, acting as ‘devils’ advocate and providing two-tiered events were successful critical teaching outcomes (Authors 2007a).

What teaching methods promote improved argumentation outcomes particularly where socio-economic and environmental issues are mixed with canonical science content?

• **Learners’ arguments about experimental data.** Learners engaged in group discussion about competing claims made on numerical data from a physics investigation showed improvement in reasoning within the task. Levels of argumentation followed school resource levels and learner experience at measuring.

What is the progression in learning to argue about evidence? How can tasks be designed to improve argumentation about numerical data.

• **Developing and researching a critical thinking curriculum for teacher education.** Student teachers who achieved highest levels of TAP for learners combined a high degree of planning with intervention to progress and steer productive group discourse. Outcomes were independent of school resource levels.

What are student teachers’ predispositions and experiences of argumentation? For those trained to use argumentation, what conditions allow these practices to survive and flourish once they are in post?

**Implications**
The curriculum in South Africa has changed from an outcomes based model (emphasising critical thinking) to one specifying content and lesson structure. As such it is much more difficult to identify where argumentation and critical thinking might fit and hence to persuade teachers that it is important (Authors, 2014a). However, there is international consensus that argumentation as part of classroom discourse about the foundations of knowledge, from canonical western science and indigenous sources, is fundamental to learning science. We discuss the potential for future argumentation research and implications for teacher education.
The Wits Talking Science Research Group: Exploring the potential of argumentation for meaning making and conceptual understanding in science

The Wits Talking Science Research Group aims to understand pedagogical approaches that create opportunities for learner talk and active involvement in science learning. We seek to understand science teacher pedagogical practices that promote learner engagement for meaning making. To this end our argumentation research has focused on understanding the potential of argumentation for meaning making and learner understanding of science concepts in secondary and tertiary education. At school level we examine both “adult-child” (teacher-learner) and “child-child” (learner-learner) classroom interactions while at the tertiary level we look at adult- adult discussions (among student teachers).

Our research findings demonstrate the emergence of unique forms of argumentation in different contexts in the classrooms we work in. For instance, we have observed learner talk begin to happen in previously ‘quiet’ classrooms; the emergence of collaborative teacher-learner co-construction of arguments during teacher led whole class discussions; development of complex teacher-learner-learner interactions; shared meaning-making in learner-learner small group engagement and development of teacher pedagogical approaches that facilitate and mediate learner argument construction through specific ways of questioning and scaffolding of learner engagement. Our other findings relate to the challenges of and potential for developing argumentation skills in multi-lingual science classrooms (Authors 2014b). It is difficult just to get learners talking even in the most sophisticated of classrooms and argumentation is an advanced form of scientific talk which both teachers and learners find difficult even with tutoring, mentoring and continued support. Argumentation is a challenge where teaching and learning happens in a second or additional language, that most are not proficient in. The implementation of argumentation is not easy. However, the emergence of the different hybrid forms of argumentation in some particularly constrained teaching and learning contexts suggests potential for its adaptation both as a teaching strategy and a learning tool in local Southern African contexts.

The Science and Indigenous Knowledge Systems Project (SIKSP)

UWC’s Science and Indigenous knowledge Systems Project (SIKSP) has for many years conducted argumentation research related to the curriculum link between argumentation and Indigenous Knowledge Systems (IKS). The SIKSP seeks to understand the role of argumentation in inclusion of other world views in science education. This research, driven by the Dialogical Argumentation Instructional Model (DAIM), is in turn underpinned by the TAP model and the Contiguity Argumentation Theory (CAT). It includes the development of science teachers’ and students’ conceptual understandings of the Nature of Science (NoS) and the Nature of Indigenous Knowledge Systems (Authors, 2007b).
The SIKSP explored the role of argumentation instruction in enhancing pre-service and practicing teachers’ ability to implement the new curriculum in multicultural science classrooms using DAIM. The SIKSP work extends beyond the region, spans all levels of schooling and tertiary education and includes investigating argumentation in both science and mathematics classrooms. SIKSP studies have confirmed the beneficial effects of argumentation instruction among learners from the primary to the tertiary level. For instance, Iwuanyanwu’s doctoral study with year one pre-service teachers illustrated the benefits of argumentation instruction in developing conceptual resources needed to solve classical mechanics problems; a topic that most teachers found difficult. The study explored the potential of DAIM to provide pre-service teachers the needed discursive communal learning environment where they communicated their viewpoints with their peers as well as reflecting on their own assumptions and came up with new ideas on how to solve given problems in classical mechanics. Another doctoral study by Ghebru in Eritrea showed that an intervention training programme enhanced pre-service middle school science teachers’ ability to organize and facilitate argument-based lessons.

Langenhoven’s doctoral study into modelling in teacher training programmes on authentic learning explicated argumentation instruction. The integration of western science and IK worldviews finds traction with the notion of de-colonising the curriculum. A further development from the SIKSP work is the Pyramid Argumentation 3D Model incorporating teaching and learning theories, DAIM, NoS, NoIKS and the Nature of Sensory Modelling (NoSM) and in the inner space, Cognitive Harmonisation. SIKSP research has been presented at conferences, over 50 refereed articles published and over 20 Masters and doctoral studies completed since 2004. The research team will explore the implications of the findings of this research in addressing teachers’ and teacher educators’ challenges of working with IK in science teaching.

References

Authors (2007a)
Authors (2007b)
Authors (2014a)
Authors (2014b)

Keywords: Argumentation, nature of science, critical thinking, Indigenous Knowledge, meaning making
TALKING SCIENCE IN A TEACHER PROFESSIONAL DEVELOPMENT PROJECT - AN INTERVENTION TO FOSTER TEACHING FOR CONCEPTUAL UNDERSTANDING

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Introduction

This symposium is proposed by representatives of the stakeholders involved in the teacher professional development intervention under discussion. The intervention was a collaboration between one of the school districts in the Gauteng Province and academics at a local university in Johannesburg (name will be revealed after the peer review process). The three presenters in this symposium will therefore the Physical Sciences subject advisor, the staff member from the university who is also the lead researcher in the project that supported the intervention; and a doctoral student whose study was the key driver of the intervention.

In this symposium we reflect on our experiences of collaborating in conceptualising, designing and implementing a teacher professional programme that has been running for three years in this Gauteng school district. In particular we discuss how we negotiated the different and sometimes conflicting objectives of our organisations and our own personal and professional orientations. The second author represents the Gauteng province of the Department of Basic Education, the GDE where he works as a Physical Sciences subject advisor, the third author is an academic at a collaborating tertiary institution while the first author is a doctoral student and was a teacher in the same district when the project was first started. He subsequently left to engage in full time study for the PhD. We also bring in the teacher’s voice through teacher evaluations of the intervention. The main objectives of the presentation are to:

- Reflect on our own experiences of coming together to collaborate on teacher professional development.
- Reflect on our struggles to meet both the GDE objectives of teacher development and learner performance as well as the Wits and NRF research requirements.
- Reflect on the actual intervention activities and our observations of teacher engagement during the workshops and laboratory sessions
- Reflect on the use of talk, argumentation and pedagogical link making strategies during the intervention and the forms of teacher uptake of the strategies.
- Reflect on our individual and collective perceptions of teacher and learner gains by the end of the third year of the intervention in 2017.
• We discuss the implications for collaborations between research institutions and Departments of Education and the funders with particular emphasis on intervention structure, duration, intensity and interpretation of outcomes.

We address a range of questions including:

1. What are the collaborative experiences of participants in a teacher professional development programme involving multiple stakeholders with divergent objectives and expectations?
2. What are the key features of the model and what theories of action of professional development informed the intervention?
3. What was the nature of participant engagement with talk, argumentation and pedagogical link making strategies during the intervention? In particular what are the emerging forms of teacher uptake of the strategies?
4. Thus, what teacher and learner gains were evident at the end of the third year of the intervention?

Literature and framework

According to Yoon, Duncan, Lee, Scarloss, Shapley (2007) teacher professional development key to improving classroom instruction and student achievement. Yet, in spite of this intuitive and logical connection, it is not easy to demonstrate that teacher professional development translates into gains in student achievement. Yoon and colleagues argue that the link between professional development and student achievement could be established if it studies could demonstrate links among professional development, teacher learning and practice, and student learning through high quality empirical evidence. Yoon and colleagues also argue that while the effects of professional development on student achievement are “mediated by teacher knowledge and practice in the classroom … professional development takes place in the context of high standards, challenging curricula, system-wide accountability, and high-stakes assessments” (Yoon et al 2007, page 3).

Yoon, Duncan, Lee, Scarloss, Shapley (2007) describe three steps through which professional development affects student achievement: it enhances teacher knowledge and skills; which improve classroom teaching; which raises student achievement. The challenge is measuring/evaluating the learner gains. “If one link is weak or missing, better student learning cannot be expected. If a teacher fails to apply new ideas from professional development to classroom instruction, for example, students will not benefit from the teacher’s professional development” (Page 3). Thus, high quality professional development programmes must be coherent and have a strong focus on content knowledge; be of sufficient duration with planned follow-up sessions; promote collective participation of all involved. It must be guided by clear theories of teacher learning and change, designed to shift teaching from traditional approaches, facilitate learner active involvement in learning. The programme must also move away from the “train-the-trainer” approach and work directly with teachers. Clearly, this is a difficult list of requirements for any teacher professional development programme to be able to achieve.
Methodology

Here we intend to describe what we did over the three years 2015-2017 in the district working with teachers from 55 schools in the district. We will describe the intervention activities and teacher engagement during the workshops and laboratory sessions. We will also explain how the concepts of talk, argumentation and pedagogical link making were introduced and modelled to teachers with follow up observations of some of the teachers as part of the first author’s PhD study.

Results

The model – here we characterise and interpret the features of the model that we used which was a hybrid format of the interventions reported in literature:

- Two-day teacher resident workshops focusing on specific topics, teaching strategies, demonstration of selected practical/laboratory activities – 3 times a year on average
- Whole day hands-on laboratory activities at the university – teachers brought to a fully equipped teaching laboratory to conduct selected experiments usually linked to the prescribed experiments for learner assessment for that year.
- Teacher engagement in discussions of own understanding of the topic/concepts with assistance from the university staff
- Discussions of differentiated teaching methods for learners with differing abilities, e.g. more traditional teaching for progressed learners and at risk learners
- Teachers provided with teaching and learning materials for the topics covered at the workshop including laboratory instructions and samples of assessment
- School based support through PLCs and by the Subject advisor and
- Controlled tests for all learners (by cluster) every term and provincial or national assessments in fourth term. Teachers and Subject advisor monitor learner grades, discuss at cluster meetings and re-strategise for underperforming learners.

Stakeholder experiences of collaboration

We will provide qualitative data in the form of narratives by each of the three authors about our experiences as well as selected teachers’ experiences of the intervention.

We will also comment on teacher uptake of strategies through the PhD student’s study

Finally, we will discuss quantitative data on learner performance over the three years 2015-2017 and implications for the collaboration and for future research and teacher development (see Table 1).
Table 1: Learner performance over the three-year period.

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<tr>
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Discussion and implications

We discuss the implications for:
- Rigorous interventions
- Collaboration between different stakeholders and sometimes conflicting institutional objectives – including teacher unions and school management.
- Lessons for universities, Departments of Education and the funders
- Intervention structure, duration, intensity, coherence, etc – theoretical underpinnings
- Documentation and interpretation of outcomes, especially determining teacher benefits and evaluating learner gains.

We believe that inter-disciplinary interventions in this and other districts would provide a holistic experience teachers and learners. We observed that with sustained support teachers gained confidence both in content knowledge and pedagogy. As Yoon and colleagues (2001) argue interventions that enhance teacher knowledge and skills improve classroom teaching which raises student achievement. However, these learners continue to struggle with other issues that affect achievement in science and other subjects, for example language and poor performance in
mathematics. We see potential value in interdisciplinary teacher professional development programmes involving science, mathematics and language interventions not in silos but in a collaborative model.

Reference

Introduction

Pedagogical Content Knowledge (PCK) is understood to be tacit, dynamic and multidimensional in nature. It is one of the theories of teaching and learning, in Kuhnian terms that similar to the development of scientific theories, has left a trail of visible milestones towards gaining consensus in the understanding of its nature. This symposium aims at sharing the developments made in the conceptualizing of PCK towards a consensus model with the science education community in the Southern African region. The symposium consist of three papers all sharing the different aspects of the developments. The first paper reflects on the development of a consensus model from two intensive international Summits I and II on PCK. The second paper presents the positioning of topic specific PCK as a significant grainsize of PCK in the newly refined consensus PCK model. The last paper, presents evidence for the conceptualisation of teachers’ PCK in the Revised Consensus Model from a collaborative learning study on teaching the mole concept. In so doing, the author attempts to fit the new model to empirical evidence. The symposium will have a discussant who will pull together all the presented aspects to enable interactive engagement with the audience.

Paper 1: Developing a model for science teachers’ pedagogical content knowledge

This paper reviews recent developments in the conceptualization of PCK in the international science education community by drawing together the discussions from the two PCK summits that were held in 2012 and 2016. The main aim of these summits was to reach consensus on a model of PCK that is strongly connected with empirical data of varying nature, and can be used as a framework for the design of future PCK studies. The purpose was also to communicate this model with the wider research community through publications and presentations. Both summits included as participants (n=25) experienced and early career PCK researchers, offering an opportunity for early career PCK researchers to be introduced to more experienced members of the PCK research community. As an international research community, the PCK research community is thinking forward about the future of research in this area and assisting early career researchers to better plan and appreciate the trajectory of research in this field.

The summits consisted of short presentations, and alternating small group and whole group sessions. In small groups, participants worked on focused tasks, which were discussed in the whole group
sessions. Both summits concluded with a model building session that included all participants. The first summit resulted in a Consensus Model of teacher professional knowledge, which was published in a book (Berry, Friedrichsen, & Loughran, 2015) and presented at various international conferences. Compared to previous models of PCK, this model aimed to connect PCK to other knowledge bases, and to classroom practice. The second summit culminated in a Revised Consensus Model that will be presented at this session and in a forthcoming book. This model distinguishes between collective, personal and enacted PCK. Further findings include the significance of the processes involved in planning and carrying out the summits. These processes are valuable in relation to the sustainability and cohesion of a research community so that there is consistency around the quality, validity and reliability of research in the field.

Paper 2: Positioning Topic Specific PCK in the Refined Consensus PCK model

The multidimensional nature of PCK emerges in the literature in various ways. A different set of studies has reported on the differentiated grain size of PCK evident when the teaching of a particular discipline and a specific topic is considered (Nezvalová, 2011; Veal & MaKinster, 1999). These authors suggested that PCK should exist at three levels, namely, at discipline, domain and topic specific levels. Some studies have looked at PCK emerging from a perspective of a group of teachers and recognized the emerging wisdom from the collective (e.g. Loughran, Mulhall, & Berry, 2004), while others have studied PCK from the position of individual teachers (e.g. Aydin, Friedrichsen, Boz, & Hanuscin, 2014). It could be reasonably argued that all the above studies present multiple perspectives of the same theoretical construct, which has over the years posed a challenge on how to refer to each grain size without ambiguity (Aydin et al., 2014). This presentation seeks to illustrate how PCK at the topic level is positioned within the Refined Consensus model (RCM) of PCK. It demonstrates this by tracking the development of chemistry pre-service teachers’ PCK in electrochemistry across the three different realms displayed by the RCM model. Data were collected using tools specifically designed to measure the pre-service teachers’ PCK in electrochemistry, administered as pre and post-intervention tests as well as submissions made as a major assignment. The analysis of test data to detect shifts in the quality of PCK was carried out using a criterion-based rubric, while a qualitative in-depth content analysis was employed on the collected assignments. Findings indicated a differentiated improvement in the pre-service teachers’ personal PCK and in their enacted PCK for planning to teach the topic. Implications drawn for science teacher educators include the uttermost importance to explicitly articulate the level or grain size of PCK under investigation in PCK studies and the realm in which the construct is located.

Paper 3: Evidence for the Conceptualisation of Teachers PCK in the Revised Consensus Model from a Collaborative Learning Study on Teaching the Mole Concept

The topic of stoichiometry, which deals with the quantitative aspects of chemical reactions, is considered difficult to teach (Gulacar, Overton, Bowman, & Fyneweber, 2013). To address this challenge, a Professional Learning Community was formed with three experienced teachers enrolled
in a post-graduate program, with the Professional Learning Community forming part of their own research study in their post graduate study. Together with their supervisors as experts, a lesson on the mole was planned, explicitly using the construct of topic-specific PCK, aligned with collective PCK at a topic level in the Revised Consensus Model, in a Learning Study. During the Learning Study, the lesson was critically discussed and improved on over three cycles. The lessons were observed and an in-depth analysis of each lesson was conducted to identify teaching episodes, which where mapped to highlight the interaction of the components of topic-specific PCK as the analytical framework for topic-specific professional knowledge in the consensus model of teacher knowledge and skill, including PCK. The impact of the Learning Study on practice highlighted that the teachers in the Learning Study delivered lessons that incorporated aspects of the collective knowledge of the professional learning community but that the enactment of the collaboratively planned lesson deviated from the collective plan due to a number of factors. These factors could be classified as teaching context, student interactions, teachers’ personal PCK, teacher beliefs and orientations, teachers’ content knowledge and general pedagogical knowledge. These emerging patters, when examining the enactment of the lesson provide empirical support for the revised consensus model and its connections.

References


STRATEGY FOR TRANSFORMATION OF TEACHERS’ PEDAGOGY IN PRIMARY SCHOOLS OF LOW-INCOME NATIONS: Case of Ethiopia

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The purpose of the current research was to try and identify the effective approach for changing the pedagogy of STEM subjects in a way that student outcomes are enhanced. The study implemented the intervention in 56 schools in the focal areas of six CTEs in Ethiopia using a yearlong intervention with dialogic teaching of physics was implemented in three group of schools and physics knowledge test pre- and post-test results were collected from 1248 primary school students. The data was analysed for difference between groups and a result that showed that the in-service strategy with experienced teachers to be statistically significantly successful. Therefore, we concluded that interventions aiming at pedagogical changes from highly didactic to dialogic should be introduced in an in-service training of experienced teachers.

BACKGROUND

Like most sub-Saharan African nations Ethiopian education is suffering from relatively lower enrolment, high dropout rates, and disappointing attainment gap. Huge and yet increasing attainment gap has been reported by different researchers in comparison with even other developing nations (Beatty and Prichett, 2012; Singh, 2014). At the background of this there is the deep-rooted tradition of using “the lecture method” for the very difficult curriculum (Abebe & Woldehanna, 2013; Alemu, 2017). To resolve the declining quality, Ethiopia launched a series of educational sector development programs (ESDPs) which were aiming at improving the quality of teaching (ESDP-V, 2015) with the introduction of active learning methods, though it did not result in considerable improvement of students learning outcomes. To support the countries initiatives with research, a three-year project (TPSS project) in collaboration with the UK ESRC-DFID was launched. The project has two phases: the first involving 10 Colleges of Teacher Education (CTEs) and the second with 60 primary schools. Beside disappointingly week teachers’ subject matter knowledge, this study reviled that teachers’ pedagogy indeed can change with implementation of the change with appropriate strategy, depending on individual and organizational contexts (Alemu, et al., 2017). The second phase of the TPSS project focusses on the implementation of Dialogic Teaching and Scientific Argumentation in upper primary schools. The second phase is so designed to test and identify the better intervention mode when such innovative pedagogical changes are introduced with the goal of improving learning outcomes. Therefore, the specific objective of the current study in this article is to investigate strategies of implementing disciplinary dialogical teaching in physics in primary schools.
This article reports the comparison of the three strategies based on the result from the physics knowledge test measures.

Theoretical Framework

Prominent educational change researchers like Fullan attest that many reform initiatives for educational improvement fail to achieve the intended change in teacher pedagogical practice (Fullan, 2007). In recent literature, other researchers are stressing that new pedagogical changes require changes in the student-teacher relationships (Dole, Bloom, Kowalske, 2016) as the teachers’ role changes from being a source of knowledge to one in which the teacher is a facilitator and self-learner. Whether due to the role change or in general due to the uncertainty in becoming as effective as before, teachers do not dare to change their ineffective pedagogy (Le Fevre, 2014). Teachers’ sense of risk and reluctance to attempt change, are further complicated with the abstract science curriculum and the very high-stakes exam contexts. In the implementation educational change literature, seriously considering the Grant and Hill (2006) factors identified from the review of massive literature,

In their experimental study of change of teachers’ pedagogy Grant and Hill (2006), identified from massive literature review Dole, Bloom, & Kowalske, (2016) had observed that teachers’ pedagogies in deed could change resulting in significant student learning outcomes and better student-teacher dynamics in the classroom as well as in schools. We also reported last year (Alemu, et al., 2017) that, in our first phase intervention with dialogic teaching in CTEs that the college teachers’ pedagogies could show significant change from teacher cantered lecturing towards somewhat student-oriented pedagogy. Furthermore, it was reported that there were large variations in the degree of change among intervention teachers and insignificant changes in students’ outcome. Better support in the implementation of the change and longer exposure to the new pedagogy is expected to bring about substantial transformation in teachers practice and consequently better students learning outcome.

METHODOLOGY

The research was conducted with a pre-test post-test control group quasi experimental design with internal replication. Data was collected from 56 primary schools grouped around the six CTEs. Participant grade 7 and 8 teachers in the implementation of dialogical teaching were drawn from three different groups:

1. those who were introduced in the first phase of the project to dialogic teaching in their own learning of physics courses during their college pre-service education;
2. those who had been given a one-week intensive in-service training in dialogic teaching in the respective CTEs with CTE lecturers who were trained and implemented the same in their classrooms in the previous year;
3. those who had been introduced to dialogic teaching in CTEs and were also given the one-week intensive in-service training by the CTE lecturers.
The intervention was supported by Scaffolding materials developed by the research team and distributed to all intervention were schools. The intervention teachers were encouraged and were given support to use dialogic teaching in their physics classrooms repeatedly over the academic year. To gather data for the purpose of the study, identical physics knowledge pre-test and post-test were administered at the beginning and towards the end of the academic year. Physics knowledge test scores from a total of 2104 were collected and results of 1248 of them were compared in groups. The 1248 of the participant primary children were grouped according to their teachers’ exposure to dialogic teaching as 187 CTE intervention, 411 in-service, 224 CTE and in-service combination groups, and 426 comparison groups.

FINDINGS

• Due to the very low level of knowledge of students and complicated problem of the use of the English language, achievement in both pre- and post-test in physics knowledge was very low (less than 50% of the maximum possible score of 26 points) in general.

• The three intervention and comparison groups showed small but statistically significant improvement between the pre- and post-test.

• With the pre-test scores as a covariate in ANCOVA analysis, Group has a significant effect (F=7.257, p=0.000), which means, at least one of the sub-groups performed better than the rest of the others.

• Being in one of the four groups does matter for students score although the difference explains a very small percent of the total variance (1.7%).

• At a significance level of 0.05, Bonferroni test revealed that only the in-service intervention subgroup mean was significantly different (M(adj)=10.20; P=0.004 and less) from the rest of the three groups.

• No significant difference was observed in the pairwise Bonferroni comparison among the rest of the groups.

DISCUSSION

In this study, the strategies investigated were introducing pedagogic change in CTEs, doing the same with in-service training of practicing teachers, and the combinations of the approaches. The longer exposure to the new pedagogy in their own teacher preparation years in CTEs and in the in-service training was assumed to be the best in reducing teachers sense of risk. To reduce the experience gap between the in-service and CTE related teachers, experienced teachers with few years of teaching experience were selected. Despite all this, the result found seem to favour those with the in-service only groups. Thus, the conclusion in answering the research question would have been that experience matters instead of the intervention, had there not been a significant difference between the in-service and the comparison groups in which still experienced teachers were involved. Hence, we conclude that interventions aiming at pedagogical change such as to disciplinary dialogic teaching, will be best introduced with in-service training and support to experienced teachers.
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TEACHERS’ INDIGENOUS KNOWLEDGE: Awareness and Possibilities for Life Science Teaching and Learning

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Introduction

The goal of science education in the African (indigenous) context is to make science accessible and attractive to learners in the classroom. According to the Department of Education (2002) this intention calls for the inclusion of indigenous knowledge into the curriculum as an imperative for science teaching and learning. Introducing indigenous science knowledge into the science classroom is likely to make learning more meaningful to learners from different socio-cultural background in the classroom (de Beer & Whitlock, 2009). Studies on teachers’ perception and views of indigenous knowledge (Dziva, Mpofu, Kusure, 2011) have been conducted; however, that of awareness that teachers have of their knowledge and its usefulness in the classroom is yet to be fully explored. The aim of this study is to explore the awareness teachers have regarding their indigenous knowledge and how it can be integrated into their science teaching. Aikenhead (2001) posit that to ensure effective teaching and learning of science in a culturally-diverse classroom, it is important that a teacher provide learners, who are from the indigenous context, the opportunity to learn science from their culturally diverse worldviews. However, teachers’ awareness of their indigenous knowledge and their ability to integrate such knowledge into their science teaching as indicated by the curriculum is a key factor in this study. Therefore, the following research question is posed to elicit teachers’ awareness of their indigenous knowledge and how they integrate it into their Life science teaching in the classroom;

1. What indigenous knowledge do teachers have in relation to life sciences?
2. How can teachers integrate their indigenous knowledge into life sciences teaching?

Background and Literature review

Indigenous knowledge is defined by different scholars differently. Hewson and Ogunniyi (2011) view indigenous knowledge as a local knowledge that has been in existence in the indigenous world for a long time. Based on experience, Indigenous knowledge is cumulative and involving (Ogunniyi, 2013) and it is revealed through practices, imitation, artefacts, paintings, demonstration and orally transmitted (Kibirige & Van Rooyen, 2007). Till date, indigenous knowledge is still in use locally by the indigenous people and in the western world through integration. It is a knowledge that is all-inclusive and covers all areas of human existence and adaptation such as, agriculture, engineering,
medicine, mathematics and several social systems (Onwu & Mosimege, 2004). Indigenous knowledge is the everyday knowledge of the common people. Decision making regarding issues of everyday life is informed by Indigenous knowledge for the local people. It is important to the cultural complex, which includes their language, informal education, systems of classification and the social interactions, which takes place within the metaphysical ideology. According to Emeagwali (2003), the local people have their own way of understanding their ecology, how they manage resources and preserve nature and ways of educating the young ones amongst them. In the South African context, the stated policy calls for the inclusion of indigenous knowledge into science teaching and learning in the classroom. The newly implemented Curriculum and Assessment Policy Statement (CAPS) emphasized on the incorporation of indigenous knowledge into the curriculum to promote a culturally-relevant science teaching (Department of Basic Education, 2012). This is because, indigenous knowledge is very important for learners’ conceptual development in the science classroom, and it often relates well with the concepts of the formal curriculum. However, learners with indigenous background are likely to experience conflicting ideas with westernized science and their existing local knowledge (Kibirige & van Rooyen, 2006). For the inclusion of indigenous knowledge to be successful, teachers need to be aware of their own indigenous knowledge first and then be able to incorporate it into the teaching and learning of science in the classroom context. For Ogunniyi and Hewson (2008) most teachers are not optimistic on the success of integrating indigenous knowledge and westernized knowledge, even though the knowledge is acceptable to them. Incorporating indigenous knowledge into science teaching helps learners to acknowledge their social identity and this might raise their curiosity and change their attitudes towards science (de Beer & Whitlock, 2009). Indigenous knowledge helps the teacher facilitate their own border crossing and those of their learners in order to ensure effective teaching and learning of science in culturally-diverse contexts (Aikenhead, 1996, 2001a). Therefore, introducing indigenous knowledge into the science classroom will play an important role in enabling learners construct their own learning, facilitate border crossing and serve as a factor in renewing and stabilizing their cultural production (Hodson, 2009).

Methodology

This study uses a qualitative research and case study approach. Qualitative researchers conduct their research in real-world settings, and they are interested in knowing how people construct their world and interpret their experiences. The study will focus on exploring teachers’ awareness of their indigenous knowledge and its possible integration into Life science teaching in the classroom. Five Life science teachers will be investigated in two different schools in the Gauteng province of South Africa. A questionnaire will be administered to participating teachers to access their indigenous knowledge. The questionnaire will focus on eliciting teachers’ awareness of what indigenous knowledge is all about and what they have. Their responses will be analyzed and then used, as a foundation, for conducting interviews. The second data will be collected through individual interview and a focus group interview with teachers to further elicit their understanding of indigenous knowledge and how it can be integrated into Life Science teaching. The interviews will be audio-
recorded and transcribed verbatim and will serve as a raw data. After the transcription process, the
data will be member-checked (respondent validation) by soliciting feedback from the interviewed
participants on the emerging findings. This will help in ensuring accuracy of the data as well as
reducing the errors that might emanate from the transcription process. The transcribed data will be
coded by assigning emerging themes to the data bits by bits transforming the data as I analyze it.
Data will be triangulated by cross-checking the data that will be collected both from interviews and
questionnaires.

This is a work in progress at this time.

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THE TVLV MODEL: A Conceptualization for Teacher-Learners’ Engagement and Learners’ Participation in the Classroom

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Abstract
This conceptual paper proposes a Teacher’s-Value-Learners’-Value (TVLV) model which attempts to explore the principle that undergirds teacher-learner engagement (TLE) and learners’ participation (LP) or Learners’ non-Participation (LnP) in the classroom. Teacher-learner engagement which may result into LP or LnP in the classroom has been top priorities for educators and policy makers because disengaged learners are more likely to struggle academically, to drop out of school, and to have behavior problems. However, the literature advances differing views on the concept of value as a precursor for the eliciting of behaviors. Ultimately, an exploration of how value underpins TLE; and how this may accentuate LP or LnP needs to put in the right perspective. The TVLV model suggests that there is an intersection of the socioculturally mediated teacher’s value, learner’s value and the value inherent in the curriculum in the classroom. Moreso, as the mediator of teaching and learning in the classroom, the teachers’ value-driven behaviors play important roles in facilitating TLE which may result in LP or LnP. The TVLV provides a veritable prism with which the concept of value is viewed especially in relation to how the socioculturally-mediated value-driven behaviors of the teacher may enhance the value-driven TLE and LParticipatory or LnPaticipatory behaviors in the classroom. An exploration of engagement and participation endeavors in the classroom using the TVLV model suggests awareness towards renewed efforts to enhance the performance of learners and achievement of teaching and learning outcomes.

Introduction and Background
Teacher-Learners’ engagement and learners’ participation in the classroom have been described as multi-dimensional phenomena vital for teaching and learning outcomes and academic achievement (Jones, 2008; Gunuc and Kuzu (2014); Ciric & Javanovic, 2016). Starmer, Duquette and Howard (2015) described learning as “an active process of making sense of what has been taught” (p. 134) although Almqvist, Uys and Sandberg (2007) viewed learning in terms of consistent change of behaviors. Temos (2016) explained that a learner is learning when s/he is actively engaged and participating in the classroom; and this may result in academic achievement. Engagement and participation have however been described using different lenses. Engagement is viewed as the amount of time allocated to educational or related activities (Almqvist, Uys and Sandberg, 2007; Kuh, 2009a)). Gunuc and Kuzu (2014) defined engagement as “the quality and quantity of students’ psychological, cognitive, emotional and behavioral reactions to the learning process as well as to in-class/out-of-
class academic and social activities to achieve successful learning outcomes.” (p. 216). The behavioral aspect of engagement is also corroborated by Klemenčič, & Chirikov (2015). According to Ciric and Javanovic (2016) “students’ [learners’] and teachers’ engagement is considered as an important attribute of behavior [...]” (p. 187). However, behavior, emotion and cognition are interrelated (Heather, Kathleen and Logan, 2013; Eisenberg, 2014); and they are vital components of value (UNESCO, 2009). In this respect, this paper argues that teacher-learners’ engagement in the classroom, which triggers the eliciting of certain behaviors, is value-driven.

Furthermore, Morgan, Martin, Howard and Mihalek (2015) seem to give a holistic description of participation as when learners, not only listen, but must be engaged in providing solutions to problems in the process of reading, writing and discussing. Learners’ participation in the classroom may also include attempting questions to volunteer answers, group work, discussions and collaboration among learners (Lee, 2014). Learners cannot be considered as participating or engaging with their teacher in the classroom in a one-way dialogue during which a teacher does most of the talking, asks questions and the learners just provide the answers. In line with this, Tesfaye and Berhanu (2015) argued that the teaching learning process may be enhanced by a dialectic relationship which promotes “a strong two way communications (Teacher students or students’ students)” (p. 29) that may result into active participation in the classroom. A dialectic relationship ensures that both the teacher and the learners participate and engage in the classroom, although, if a learner is quite in the classroom, it may not necessarily mean that s/he is not participating or engaging. Moreover, learners’ participation, like engagement, have also been explained and examined in terms of participatory behaviors (Goggins & Xing, 2016; Shiota, 2018). Eyal, Sagristano, Trope, Liberman and Chaiken (2009) posited that there is a relationship between behaviors and value which may be “highly variable in magnitude” (p. 35). In view of the above discussions this paper argues that learners’ participation in the classroom is also a value-driven phenomenon.

Consequently, Tedesco-Schneck (2016) explains participation as a process of active engagement. This suggests that participation and engagement are dialectically-related. As explained above, the two concepts also trigger psychological responses which result into the eliciting of certain behaviors (action or inaction). Therefore, engagement and participation are essential ingredients for active learning (Justin & Karla, 2017) and academic achievement (Gunuc and Kuzu, 2014). Moreover, learning also involves the eliciting of behaviors, hence like engagement and participation may be considered as a value-driven phenomenon. DiSalvo (2017) introduced the term Value-driven Learning to “create a conceptual framework for how we can build upon play and interest of learners into sustained engagement with learning” (p. 1). Therefore, this paper proposes that learners’ participation, teacher’s-learners’ engagement and learning in the classroom exist in a triple dialectic relationship; and they trigger the eliciting of value-driven behaviors (Figure 1). However, Boe, Henriksen, Lyons and Schreiner (2011) posited that an individual’s behaviors which are value-driven are associated with and impacted by his/her social contexts (Vygotsky’s cognitive development (Vygotsky, 1978, 1987; Kozulin, 2015)); situated learning (Lave & Wenger (1990)).
Ultimately, the issue of teacher’s-learners’ engagement which is central to learners’ participation coupled with teaching and learning endeavors in the classroom has been top priorities for educators and policy makers (Lee, 2014). This is because participation and active engagement in the classroom are essential and critical components for learners’ success in a variety of classroom contexts (Tatar, 2005; Lee & Reeve, 2012; Wright, 2014). Conversely, learners’ non-participation may result in some unpalatable consequences and underachievement resulting from their being bored with the tasks or activities in the classroom. This may lead to learners being disengaged from school, struggle academically, have problem behaviors; and eventually drop out of school (Lee, 2014). Academic performance (in terms of failure) may therefore result from longstanding disengagement from school or classroom activities. Nevertheless, learners’ poor academic performance may be prevented if learners’ engagements are enhanced (Lee, 2014).

Fig. 1: Triple dialectic Relationship of Engagement | Participation | Learning in the Classroom

In this paper, we conceptualize teacher-learner engagement and learners’ participation in the classroom in terms of value-driven behaviors. We argue that the teacher’s value is of utmost importance in this regard. Reeve (2009) reported the importance of teachers’ value in either “learners’ needs frustration” (p. 100) when learners are not participating in classroom activities or learners’ “psychological need satisfaction” (p. 100) when they engage in classroom activities. In the same vein, Taylor and Booth (2015) reported that teachers’ conceptions (value) “underpin and inform their teaching approaches, which ultimately influence [learners’] learning outcomes” (p. 1299) or achievement behavior (Eccles, 2009). This author explains that achievement behaviors include choice, motivation, persistence and quantity of efforts, cognitive engagement (participation), and actual performance of the learners. This paper therefore theorizes on a Teacher’s-Value-Learners’-Value (TVLV) model which suggests that teacher’s-learners’ engagement and learner’s participation in the classrooms are predicated on value-driven behaviors that are elicited as a result of the ‘value of’ or ‘value for’ teaching and learning imbued in the teacher and learners by their sociocultural backgrounds. In the next section, we explore an understanding the concept of value.
Conceptualization of Value – What “is” or What “ought to be”

The grundnorm of the TVLV upon which this paper is premised considers the classroom as a social context where the teacher’s value, the learner’s value and the value inherent in the curriculum intersects. But what is value? Value is an abstract, yet an important concept that has been used in different ways across multidisciplinary and cultural contexts (McLaughlin, Rossimeissl & Wise, 2001). Kostrova (2018) stated that the “concept of value is widely used in various fields, and it has recently become the subject of empirical research, [h]owever, there is no common understanding of what it is” (p. 171). In the light of this, Kostrova reported arguments which support an understanding of value based on “what [it] ought to be” (p. 171) rather than an understanding based on “what [it] “is” (p. 171). Since the concept of value is slippery, how it is used may depend largely on the prism with which the user is viewing it; and perhaps the clamor for an understanding of the concept based on what ‘it ought to be’. Value, like beauty, is therefore “in the eye of the beholder” (Hungerford, 1878). In addition, contexts have been found to play a major role in the usage and meaning given to the concept of ‘value’ (Schmidt, Skvortsova, Kullen, Weber and Plassman (2017). In this paper, we adopt the definition of the Oxford online Dictionary (2018) of value as the “relative importance, worth, usefulness of something” (an item (specific object), idea, person, a state of being etc.) to an individual, that forms a vital part of his/her life. Notwithstanding this definition, value has been conceived in various ways in the literature (Pinkett, 1990; Wilson & Dufrene, 2009; Environics, 2014)). We consider an item, idea, person, or a state of being as value objects; and the individual who values (regards or assess or evaluates) a value object as a valuer. The importance of a value object to a valuer is subjective (Eccles, 2009) and unique, whereas this same value object may be less significant to another individual. We consider value using two perspectives, ‘value of’ and ‘value for’ in this study. Moreso, the two perspectives are dialectically inter-related, that is, one cannot exist without the other.

‘Value of/for’ a value object. In this study, we argue that the ‘value of’ a value object concerns a state of the value object in which its importance, worth or usefulness is potentially resident (or locked) within it. This implies that the ‘value of’ the value object is in a ‘potentially inherent state’ in the value object. We refer to this as intrinsic, innate or inherent value; and consider it to mean that the relative worth (including cost), usefulness or importance of the value object resides inherently in a ‘potential state’ in it. We propose ‘value of’ as the importance, worth or usefulness inherent in a value object which empowers it with the ability to cause an individual (a valuer) to elicit behaviors towards or away from it. We consider that this may occur in two ways: i) the inherent ‘value of’ the value object may trigger curiosity or interest from a valuer; ii) a valuer, as a result of his/her interest or curiosity recognize the ‘value of’ the value object. In the first case, the inherent ‘value of’ the value object acts as an extrinsic value which triggers certain behaviors in the valuer. However, in the second case, the valuer is triggered by his/her intrinsic value to enact certain behaviors i.e. the valuer has ‘value for’. In essence, considering the first instance, the valuer may not have intrinsic value for the value object but may be attracted to it as a result of the intrinsic value of the value object. Moreover, in the second case, the valuer must necessarily be prompted by his/her intrinsic value for him/her to elicit
behaviors towards the value object. However, if the valuer elicits behaviors away from the value object, then we consider that s/he does not have ‘value for’ the value object.

The two instances ((i) and (ii)) suggest that the ‘value of’ a value object may not be recognized except a valuer does so. In other words, a value object may not be enunciated as ‘valueless’ or ‘valuable’ except if pronounced as such by a valuer. In essence, there can’t be ‘value of’ without a valuer. Yet, our argument is that the ‘value of’ a value object is inherent in it whether a valuer evaluates or assesses it or not. Only that a valuer pronounces whether the value object is ‘valuable’ or ‘valueless’ depending on his/her own subjective assessment or evaluation. We argue that a valuer pronounces a value object as ‘valuable’ if the ‘value of’ the value object aligns with the ‘value of’ the valuer; but if the ‘value of’ the valuer misaligns with the ‘value of’ the value object, the valuer may pronounce the value object as ‘valueless’. On one hand the ‘value of’ a value object aligns with the ‘value of’ a valuer when through psychological processes the valuer has internalized the ‘value of’ the value object; and then come to terms with it – the valuer elicits behaviors towards the value object. On the other hand, the ‘value of’ the value object misaligns with the ‘value of’ the valuer, when through the same processes, the valuer has not come to terms with the ‘value of’ the value object – then the valuer elicits behaviors away from the value object. Furthermore, we suggest that a valuer’s ‘value for’ a value object may result if the ‘value of’ the value object aligns with the ‘value of’ the valuer; and the valuer thus elicits behaviors towards the value object. This alignment of value of the value object and valuer may arise when: a) the ‘value of’ a value object triggers psychological processes in the valuer to elicit certain behaviors towards it; and b) when the intrinsic ‘value of’ of the valuer aligns with the ‘value of’ the value object. As in case (a) above, the eliciting of behaviors was triggered by an extrinsic value (from outside the valuer). However, in case (b), the eliciting of behaviors was triggered by the intrinsic value (inherent in) of the valuer.

**Conceptualizing the TVLV model**

We argue in this paper that the value-driven behaviors elicited by teachers may prompt participation or cause non-participation of learners in the classrooms. The teachers’ behaviors are examined in tandem with learners’ value-driven participatory/non-participatory (action or inaction) behaviors. We propose a Teacher-Value-Learners’-Value (TVLV) model for the intersection of value within the social context of a classroom such as a Natural Sciences classroom. This intersection elicits a Teacher-Behavior-Learners’-Behavior (TBLB) interrelationship, since behaviors are value-driven, as previously alluded to. This interrelationship may thus result into an action or inaction from the learners. The interrelationship may elicit an action from the learners if the TBLB triggers Teacher-Behavior-Learners’-Participation (TBLP) moments whilst it generates Teacher-Behavior-Learners’-non-Participation (TBLn-P) moments if it elicits inaction from learners. We refer, on the one hand, to the value-driven behaviors of teachers which elicits TBLP moments in the classroom (or triggers learners’ participation in classroom tasks/activities) as “Woah-Teacher-Behaviors” (WTB). These kinds of behaviors elicit ‘Woah moments’ in learners. The Merriam-Webster dictionary (2018) describes ‘Whoa’ as “... a strong reaction (such as alarm or astonishment)”. On the other hand, we refer to the
value-driven behaviors in teachers which elicits TBLn-P moments (or cause learners’ non-participation in classroom tasks/activities) as the “Ow-Teacher-Behaviors’ (OTB). The Cambridge dictionary (2018) describes Ow “as being used to express pain”. We suggest that learners are pained arising from certain teachers’ behaviors in the classroom which may result into their (learners) being disconnected and non-participating in classroom tasks/activities.

We conclude that an understanding of engagement and participation endeavors in the classroom using the TVLV model raises the awareness towards renewed efforts to enhance the performance of learners and achievement of teaching and learning outcomes. We note, albeit cautiously, that this is the first attempt of discussions on the TVLV model. We notice that such endeavors are scarce in the literature and most discussions therein seem to centre on teachers’/learners’ behaviors without foregrounding them in value as done in this paper. The proposed Teacher-Value- Learners’-Value intersection (TVLV) and how this may generate WTB or OTB in the classroom is represented in Figure 2 below:

Figure 1: The Teacher-Value-Learners’-Value (TVLV) Model for the intersection of value in the classroom.
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LEARNER PERFORMANCE TRACKED BACK TO PEDAGOGICAL TRANSFORMATION OF CONTENT KNOWLEDGE

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Abstract
This paper presents the investigation of the actual link between pre-service teachers; enacted TSPCK in teaching the topic of organic chemistry and learner performance. In achieving the purpose of the study, a class of seventeen (N=17) physical science pre-service were exposed to explicit discussions on the knowledge components for transforming content knowledge of organic chemistry. Following the discussions, five of the pre-service teacher (N=5) were followed into the classroom teaching on functional groups, nomenclature and physical properties of organic compounds. The learner achievement test was conducted prior to and immediately after the pre-service teachers’ lessons on the concepts of organic chemistry taught. Afterwards, the learners were asked to complete a learners’ view questionnaire which describes components of teacher knowledge for teaching. The analysis of data was done using the qualitative in-depth method for evidence of TSPCK and the links to learner responses. Learner achievement tools analysed using a memorandum of correct answers. The overall findings revealed a connection between episodes displaying interaction of specific TSPCK components to learners’ performances on the concepts. The implications of the study were discussed.

Introduction

Teachers play a significant role when examining issues relating to the classroom teaching and learning. Since learners can hardly develop scientific understanding without access to professional science teachers, special attention is thus paid to developing teacher knowledge for teaching. Pedagogical Content Knowledge (PCK) has been regarded as the most significant domain of teacher knowledge which makes content knowledge accessible to the learners (Shulman, 1986).

PCK has been a fruitful construct that many researchers have used to explore the development of teacher knowledge and classroom practices. PCK has also been successful in generating a framework to identify and describe what could be considered important knowledge for teaching, however, “very little, if anything at all is known about the link between PCK and student learning” (Cross & Lepareur, 2015, p. 47). Likewise, Ohle, Boone and Fischer (2015) argue that very limited studies have critically examined science teachers’ enacted PCK and how that affects learners’ learning. This is a wide gap in the literature which this study purposed to fill by developing pre-service teachers’ PCK within a...
specific topic and then examine how that relates to learner performance in the same topic. At the topic specific level, quite a number of studies have used the lately developed construct of Topic Specific PCK, TSPCK (Mavhunga & Rollnick, 2013) to develop teachers’ knowledge for teaching science topics (e.g. Pitjeng, 2014; Mavhunga, 2017). The studies reported increase in the growth of the participant teachers’ knowledge for teaching science topics using the construct of TSPCK. Hence, there is the need to establish whether there is a positive influence of acquired TSPCK by pre-service teachers on learners’ performance in a given topic. To achieve this, this study focused on developing the TSPCK of a group of pre-service teachers and then examining their quality of TSPCK demonstrated in the classroom teaching of organic chemistry in relation to learner performance in the same topic.

Theoretical Framework

PCK is presently considered as the teacher Topic Specific Professional knowledge in both the planning and actual classroom teaching (Gess-Newsome, 2015) for improving classroom practice and learners’ understanding of a specific topic. The model of teacher professional knowledge and skill including PCK developed by PCK researchers and the model of TSPCK developed by Mavhunga and Rollnick (2013) served as the theoretical framework in this study. At the topic specific level, the transformation of content knowledge occurs when a teacher engages certain five content-specific knowledge components in reasoning, planning and actual teaching of the concepts of a given topic. TSPCK is concerned with the transformation of content knowledge of a given topic at a time from a planning and classroom enacted point of view. The content-specific knowledge components include: Learner Prior Knowledge; Curricular saliency; What is potentially difficult for learners to understand; Representations with analogies; and Conceptual teaching strategies (Mavhunga & Rollnick, 2013). Both the understanding of the knowledge needed to transform concepts in a topic and the actual skills of how to use such knowledge generate PCK which is specific to that topic. As a strategy for preparing pre-service teachers who are traditionally known to have little or no PCK, emphasis is placed on developing their PCK in a given topic per time (Rollnick & Mavhunga, 2015). This is done by engaging the pre-service teachers in discussions that explicitly explain the pedagogical transformation strategies using five knowledge components of TSPCK.

Methodology

A mixed methods research design was employed with the case study of 17 physical science pre-service teachers in their 3rd year of study as the research strategy. The exploration of the nature of the link between the quality of TSPCK vs. learner performance, presented in this paper, was explored with a sub-set of 5 pre-service teachers. Prior to the classroom teaching of organic chemistry, all pre-service teachers attended an intervention located in chemistry methodology course. The intervention happened over six weeks with explicit discussion on using TSPCK construct to transform content knowledge of organic chemistry. Following the intervention, three of the five pre-service teachers delivered two lessons on the concept of functional groups and nomenclature and the other two taught the concepts of physical properties and structures of organic compounds. The lessons
delivered by each pre-service teacher lasted for 1 hour 20 minutes. The total number of sixty (60) Grade 11 learners and thirty (30) Grade 12 learners participated in this study. They were all high school physical science learners from a Government-owned township school in South Africa. The sources of data for this study included: the video recording of the lessons; lesson plans; pre-and post-achievement test conducted with the learners; learner views questioning; and post lesson interviews with the pre-service teachers. Similar to the PCK study by Park and Chen (2012), a method of in-depth qualitative analysis was employed describing the quality of pre-service teachers’ lessons as seen through TSPCK episodes. The 4-criterion based TSPCK rubric (Miheso & Mavhunga, 2017) was used to quantify the observe TSPCK episodes and define the participants’ quality of TSPCK enacted in the lessons. Rasch Model Analysis was employed to estimate person measures and item difficulty on the pre-and post-learner achievement tests. The Pearson’s product moment correlation coefficient (r) was calculated using SPSS to establish the correlation between the enacted TSPCK and learner performance. The learner views were analysed using descriptive statistical analysis comparative qualitative content analysis.

Findings and Conclusion

The analysis of data revealed three important findings. First, the quality of pre-service teachers’ enacted TSPCK was a function of their understanding of misconceptions in learners’ responses, emphasis on important of concepts relating to the identified misconceptions and use of symbolic representations to support explanations. Second, the change in learners’ performance in the pre- and post-achievement test seemed to increase in positive strength in the cases of pre-service teachers who demonstrated high quantity of sophisticated TSPCK episodes while teaching. The strong correlation seemed to be connected to the extent of interactive use of specific-knowledge components that the pre-service teachers demonstrated while explaining each concept involved. Third, all learners in the three achieving abilities viewed all components of teacher knowledge as important but to different extent in making them understand organic chemistry concepts. The analysis showed that the low-performing learners in the case of four pre-service teachers seemed to describe certain teacher knowledge components as less important compared to high and middle performing learners. The low performing learners seemed not to view teacher understanding of their prior knowledge as important, they rather valued teachers’ efforts to ask them questions in order to evaluate their understanding during the lesson. The overall findings in this study revealed that the extent of interactive use of content-specific knowledge components in explaining concepts influences learners’ performances on the concepts. It is envisaged that more efforts would be put into developing pre-service teachers’ knowledge for teaching science topics with the purpose of improving learners’ performance.

References


Abstract

Negative experiences by learners at the gateway phase (grade 9 to grade 10) due to perceived uninteresting content in natural sciences or poor teaching on the part of the teachers has a detrimental effect on learners. There is evidence that many Natural Science teachers are not trained in the physics content component of the subject, Hestenes, Megowan-Romanowicz, Popp et al (2011), Chisholm (2012). This has been identified as the major factor affecting learners’ achievement and interest in the sciences. The curriculum structures play an important role as teachers enact their understanding of what is to be taught, and what is to be learned. The study of Natural Sciences in our high schools is a basic-foundation subject for learners who would be going on to do Physical Sciences as a matric subject. This paper focuses on the effect of a Modeling Instruction approach on Pre-Service Teachers’ conceptual understanding of electricity in a PGCE science module. The modeling approach is an inquiry-based methodology, Hestenes et al (2011), Barlow, Frick, Barker, and Phelps (2014). The following questions were asked; What are the demographics of the in-service teachers and the implications for the teaching of Natural Sciences? What is the effect of modeling instruction on teacher test scores? An analysis of test scores and a survey of teacher experience was also carried out. The findings of the study shows there is positive outcomes for modelling instruction as a strategy for teaching physics content of Natural Science to Pre-Service Teachers. The researchers recommend the use of modeling instruction for teaching the physics contents of Natural Sciences to help learners learn science better and to see the usefulness of the subject at the Junior High School level.

Keywords: Pre-Service Teachers, Learners, Modeling Instruction, Test scores, Teacher Experiences.

Introduction

There has been a significant decline in the proportions of high school learners choosing Physical sciences at grade 10. Concern has been raised about the implications of these declines as it will impact the supply of future scientists and the scientific endeavour in South Africa, (Chisholm 2012, SAGNA 2016). The decline is in the proportions of learners who mostly had had enough with Natural Science, (Lyon and Quinn 2010). This realization, along with evidence that some teacher are not experts at pedagogy or contents as it relates to Natural Sciences, led to the conclusion that all declines in science are linked to complexity of interrelationships between curriculum, school, teacher, student and societal factors. According to Strassburg, Meny-Gibert and Russell (2010), the teacher is the lead in
class and facilitator recognized in a formal class setting. This paper will explore an intervention targeting Natural Science teachers.

**Literature**

It has been reported that learners who do not choose Physical Sciences in grade 10 did so because they found the Natural Science to be un-interesting and unengaging for them, (Lyon 2010, Harlen 2012). Lyon et al (2010) found that the most effective approach to encourage learners to take up Physical Sciences at grade 10 is to ensure that the Natural Sciences classes are relevant, engaging, interesting and enjoyable. The comments of teachers about the importance of contextualizing learning and students’ suggestions for more hands-on science experiences, because grades 10 learners are of the opinion that their most recent experiences in grade 9 was the major influence on the decisions not to take Physical Sciences (Harlen 2012, Lyon et al 2010). The NPC (National Planning Commission) findings acknowledges the role of school and classroom-based issues as decisive in the functioning of a school and the output of its results in whatever form. The specific analyses of teacher quality have linked it to what teachers know (content knowledge), the ability to convey complex concepts and ideas as well as their commitment and motivation to teach (pedagogical-content knowledge), (Wildeman 2010, NPC 2011, Carnoy et al. 2011, Taylor 2011). Using the constructivist theory, the dominant mode of knowledge building in this regard is through inquiry, (Hestenes, Megowan-Romanowicz, Popp et al 2011, Harlen 2012). Mourshed, Chijioke & Barber (2010) in analyzing the McKinsey report, argues for an approach that takes diversity in the classroom seriously and structured teaching and learning strategies that take different starting points and experiences of learners in classrooms seriously.

**Objectives of the Study**

The focus here is on the assessment of Pre-service teachers who do not have prior training in the teaching of physics components of Natural Sciences. The objective of this paper is to see if the strategy of using modeling instruction in the classroom will bring back and will maintain the spark in Junior High School science for the advantage of Senior High School science.

**Research Questions**

The following research questions were asked;
- What are the demographics of the Pre-service teachers and the implications for the teaching of Natural Sciences?
- What is the effect of the modelling instruction approach on Teacher test scores?
- What are the perceptions of Pre-Service teachers about Modelling Instruction?

**Methodology/Research Design**
This is the conceptual structure within which the research is conducted and it includes the description of the collection, measurement of variables and analysis of data. The current study used a case study research design and an exploratory case-study approach. The design facilitated the collection of information on Pre-Service teachers and the effect of ‘Modeling Instruction’ approach on their performance. It yielded information which was analysed using descriptive and inferential statistics.

**Result and Discussion: Demographics**

Table 1 shows there are more females than males, that is about 64.3% are females. This is in agreement with the studies of Van Der Berg and Burger (2007), UNESCO (2011) and Mashiya (2014). Out of the number under study, about 85.7% had studied any form of physics only to their first (1st) year in the university, while 14.3% had any formal physics to their matric level only. The data showed that about 70.4% had teaching experience of various number of years. Only 28.6 do not have any teaching experiences. This is also in agreement with the findings of Van Der Berg and Burger (2007), that individuals joining the teaching profession are the younger and less educated in those areas or field they find themselves teaching.

**Research Question 2: Effect of Modeling Instruction**

The post-test result in fig.1 below shows great improvement in performance for the topic ‘Electricity’; with improvement from 10 marks to 33 marks. This reflects the fact that these In- Service teachers are getting to the heart of modeling instruction. Harlen (2012) referred to it as learning through scientific inquiry.

![Fig. 1: Pre-Service Pre-Test and Post-Test scores obtained in Electricity](image)

The U.S. DoEd (2001) report that ‘repeated findings demonstrated greater gains for students in physics content knowledge when compared to physics students of the same teachers in the year before the teacher implemented the program and students in alternative physics reform programs. These students exceeded the performance of the comparison groups by margins that in some cases
exceeded two standard deviations’. Giving the peculiar cohort of this group of Pre-Service teachers, the result from the data for the paper is consistent with the findings of the U.S. Department of Education.

**Research Question 3: Pre-Service teachers’ perception of Modeling Instruction**

The Pre-Service teachers’ perceptions indicated that they gained a better perspective from the teaching and learning classroom environment; negotiation amongst themselves and the class, inquiry learning as learning by investigating, relevance of realistic task, representing data in various ways (complex), challenging, stimulating high-order questioning and thinking were accomplished as in figure 2 above. This is in agreement with Barlow, Frick, Barker and Phelps (2014) and Warner et al (2017).

**Conclusion**

The use of Modeling Instruction for the Pre-Service teachers has led them to better understanding of the topic ‘Electricity’ which translated into better achievement in the physics test scores. This approach facilitated the development of more student-to-student interaction and negotiations along lines of discussions and arguments, which is also the findings of this paper.

**Reference**


NATURAL SCIENCES TEACHERS’ CONCEPTUALISATION OF ‘SCIENCE AND SOCIETY’ IN SOUTH AFRICAN CURRICULUM DOCUMENTS

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Abstract
This study investigated how South African teachers conceptualise and use science and society themes when teaching Grade 9 Natural Sciences. Pedretti & Nazir’s (2011) typology provided a theoretical framework for this qualitative, small-scale study. Two research instruments were developed using the NS CAPS (DBE, 2011). A questionnaire was administered to 32 Grade 9 NS teachers from Johannesburg government schools. Three teachers participated in a semi-structured interview. Time constraints, deviation from content and inapplicability were cited to justify limited science and society practices. Participants communicated belief in the ‘superiority’ of science and were insensitive to potential barriers for non-western students. Results revealed over-reliance on work schedules and textbooks, and orientation towards traditional school science.

Keywords: Science education, science and society, qualitative, curriculum, South Africa

Introduction
Basic science education is important for developing a democratic and equitable society (Mansour, 2009). South African has seen extensive curriculum reform and although the relevance of science in society has been emphasised, with each revision the curriculum has moved further from science in society concerns, towards a more traditional conception of science.

This study explores how Grade 9 NS teachers understand and use the science and society themes found in the Natural Sciences (NS) Curriculum and Assessment Policy Statement (CAPS) (Department of Basic Education [DBE], 2011).

Literature review
Science and society pedagogy focuses on scientific and technological developments from within cultural, economic, social and political contexts (Mansour, 2009). Emphasis on science and society in the South African context could increase accessibility for students.

The realisation of science and society objectives is dependent on teachers’ ability to integrate multiple epistemologies within their own belief systems (Mansour, 2009). Personal values and
identity shape teachers' orientation to science teaching. Teachers decide how to read and implement the curriculum (Aikenhead, 2003). They prioritise personal beliefs over the intended objectives of a new curriculum, consequently implementing policies superficially while retaining old beliefs and habits (Witz & Lee, 2009). South African reform and implementation initiatives have underestimated this factor.

Pedretti & Nazir's (2011) framework for science and society pedagogy forms part of this study's conceptual framework. Their typology of six STSE currents allowed me to map science and society themes in the NS CAPS.

![Figure 1: The STSE currents (adapted from Pedretti & Nazir, 2011:607-608)](image)

Four of these currents, i.e. 2 (historical), 3 (logical reasoning), 4 (value-centred) and 5 (sociocultural), were identified in the NS CAPS (Specific Aim 3 and the preamble).

Specific Aim 3 states “learners should understand the uses of natural sciences and indigenous knowledge in society and the environment” and that NS should help develop “appreciation of the history of scientific discoveries, and their relationship to indigenous knowledge and different world views” (DBE, 2011:10).

In the preamble, four currents were identified. The inclusion of African Indigenous Knowledge Systems (sociocultural current) is suggested and science is described as "the cultural heritage of all nations", arguing that, "in all cultures and in all times people have wanted to understand how the physical world works and have needed explanations that satisfy them" (DBE, 2011:8). There is implicit reference to scientific literacy in the phrase "science prepares learners for active participation in a democratic society that values human rights and promotes responsibility towards the environment" (DBE, 2011:9). Teachers are instructed to consider historical and social contexts, science as a tool for social justice and "practical and ethical consequences of decisions" (DBE, 2011:8-9).

**Aim of the study**

This study focused on Specific Aim 3, the preamble, and work schedule in the CAPS. The research questions were:
• How do Grade 9 Natural Sciences teachers understand and value science and society themes as outlined in the Natural Sciences Curriculum and Assessment Policy Statement?
• How are Grade 9 Natural Sciences teachers’ stated practices influenced by science and society themes as outlined in the Natural Sciences Curriculum and Assessment Policy Statement?

Methodology

This small-scale, qualitative and inductive study was situated in the interpretivist paradigm.

Using convenience sampling 32 Grade 9 NS teachers were recruited from the Johannesburg region. Participants varied in age, race, languages, qualifications and teaching experience. Half of the participants were from township schools and the remainder from former Model-C schools. The questionnaire, consisting of open-ended and closed Likert-type questions, was used to record teachers’ reported use of science and society tasks identified in the NS CAPS, influences on lesson planning, and beliefs about science and society education.

Additionally, individual semi-structured interviews explored contextual factors. Three teachers were selected for interviews using purposive sampling. Participants were informed of intended uses of data and ethical concerns of confidentiality, anonymity and voluntary participation.

Findings and Conclusions

Grade 9 NS teachers’ understanding and valuing of science and society themes in the NS CAPS
Teachers’ responses were influenced by personal beliefs about science education. Most participants (78%) felt students should understand how science is used in the real world, and thus improve their understanding of scientific principles. Some participants championed the ‘superiority’ of scientific knowledge and explanation.

Teachers viewed their role as developing the discipline of science, encouraging students to think scientifically, and preparing students for further studies (Figure 2). An interview participant argued that her objective was "to train kids in the scientific method and in understanding and in questioning".
Overall, participants expressed that the focus of junior science is the learning of scientific concepts and that science and society themes are secondary, illustrated by the comment "the Grade 9 syllabus is so full that there isn’t much time to spend on societal issues".

**The influence of science and society themes in the NS CAPS on Natural Sciences teachers’ stated practices**

Most participants (96.9%) reported close adherence to the NS CAPS. Reasons for compliance were to ensure content coverage (29.9%), national common papers (18.8%), pace setting (12.5%), simplified lesson planning (15.6%), and compliance with the Department of Education (12.5%). The majority of participants rely heavily on textbooks (65.7%). Some suggested science and society aspects of the NS CAPS, such as the history of science, are not sufficiently represented in textbooks. An interview participant further suggested that the preamble to the NS CAPS is "not fully expressed in the schedule". Several participants felt incorporating science and society was beyond their scope of expertise and others emphasised limited student abilities.

Teachers should make students aware that western science is only one way of knowing about the world (Pedretti & Nazir, 2011). Another way of knowing about the world is through African Indigenous Knowledge (IKS). Figure 3 shows most teachers regarded inclusion of IKS as important.

Some teachers provided examples of IKS like “plants for medical science”. Others commented on the cultural value of IKS (25.0%) e.g. “this is our land and our resources; our ancestors used it to survive". However, others felt IKS is a sub-section of the history of science and not current scientific knowledge (25.0%). Interview participant 3 argued IKS can be referred to only if explained using western science. Comments showed that teachers believe the CAPS does not link topics with IKS examples, and that if incorporated, it is in addition to specified content.
Overall, participants did not communicate clear understanding of science and society in the NS CAPS. Participants justified limited science and society practices by citing time constraints, deviation from content, and inapplicability. Participants used the work schedule without considering the preamble where science and society ideology predominately appears.

Several recommendations can be made. The prescriptive nature of the NS CAPS needs to be critically investigated. Over-reliance on work schedules and textbooks has resulted in limited science and society practices. Science education needs to be more orientated towards the South African context. Such reform is conceivable using the existing NCS if teachers are given support. A deliberate effort to promote teachers’ understanding of science and society approaches is required.

References


PRESERVICE TEACHERS’ UNDERSTANDING OF STEM AND STEM LESSON PLANNING
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Introduction

Starting as early as the 1990s STEM (Science, Technology, Engineering and Mathematics) education has been gaining popularity (Bybee, 2010). The components of STEM have been clearly defined but the teaching of STEM is defined in many ways (Breiner, Harkness, Johnson, & Koehler, 2012). In this current day and age every school from preschool to university is looking to expand their “STEM” curriculum. Therefore, elementary teachers should be prepared to teach STEM lessons.

Preservice elementary teachers take methods courses in each of the disciplines (mathematics, science, social studies, etcetera) but where do elementary preservice teachers learn to plan and deliver STEM lessons? Additionally, most elementary teachers are trained as generalists (Schwartz & Gess-Newsome, 2008) and often do not feel comfortable teaching Mathematics and Science as independent subjects (Weiss, Banilower, McMahon, & Smith, 2001) let alone in an integrated fashion.

This study looked at what are preservice elementary teachers’ understandings of STEM and planning for STEM lessons after explicit modeling and practice in elementary science and math methods courses?

Sample

This study took place during the Spring 2018 semester at a small university in the US. The sample were selected by convenience from two classes that the researchers were teaching. There were 15 students involved in the study.

Method and Data Collection

There were several pieces of data collected during this study; responses to the STEM survey before beginning instruction about STEM (pre-assessment), after the pre-service teachers had experienced two STEM lessons modeled in their methods courses (middle assessment), and after planning and teaching their own STEM lesson (post assessment), lesson plans and video of STEM lesson taught. The STEM survey was an open-ended electronic survey that collects pre-service teachers’ definitions of STEM, examples of STEM lessons and in the post survey an explanation of planning for STEM
lessons. This survey was given in class through the universities’ digital platform. The survey was vetted for validity through two other Mathematics and Science educators who found that the survey was a valid way to determine the pre-service teacher’s understandings of STEM and STEM lesson planning.

Data Analysis

The surveys (pre, middle and post), lesson plans and video recordings were then transcribed into an excel spreadsheet. Codes were created using the constant comparative method. The two researchers met to discuss the codes and develop a code book. Once a set of codes were determined the researchers independently coded and then met to discuss. Any disagreements were discussed and the researchers agreed at a rate of greater than 80%.

Findings

Through the survey, lesson plans and lesson reflections, several trends in pre-service teachers’ understandings of STEM were found. In the preassessment, 14 of the 15 students identified that STEM stood for science, technology, engineering and mathematics. Three of the students identified it as a curriculum or curricular approach. One student defined STEM as being “for students who are advanced (in the four subjects) and are challenged more and given different types of assessments than other people.” Using this as information to inform the explicit modeling of STEM lessons in the mathematics and science methods courses, the researchers included explicit reflection on how the lessons integrated a combination of the four subjects. In the lessons modeled, three of the four STEM subjects were integrated, with objectives and assessments planned for the lessons.

After planning and teaching a STEM lesson to students, the pre-service teachers reflected on their planning and constructed a final response for: What is STEM? In the post assessment, trends in definition of STEM among the pre-service teachers included hands on (7 of 15 teachers), real world (4 of 15 teachers), integration of subject areas (9 of 15 teachers), student centered (6 of 15 teachers), and incorporates problem solving (3 of 15 teachers). Ten of the pre-service teachers specifically commented on the number of subjects needed to be considered STEM (one teacher said 2 of 4 disciplines needed, 5 teachers said 3 of 4 disciplines needed, 3 teacher said STEM must include all 4 disciplines).

This finding was explored further when analyzing pre-service teacher responses about their planning process and responses to the prompt: How do you teach STEM? In the pre-assessment, teachers responded quite briefly. The main trend in responses was eight preservice teachers said that lessons should be hands on. These preservice teachers included a variety of specifics including “use iPads and have students build something with different types of materials.” Three preservice teachers stated that they were not sure how to teach STEM.
It was found in the post assessment response to; “How do you teach STEM?” preservice teachers wrote more detailed responses, with ideas in including: start the lesson with a question (4 of 15 teachers), students should create and implement a plan (10 of 15 teachers), students should collect data (4 of 15 teachers), explicit reflection with students on how STEM was part of the lesson (5 of 15 teachers), and student should make observations (2 of 15). Six of the preservice teachers simply summarized the lesson that they taught without providing insight of specifics of how to generally teach a STEM lesson.

It is noteworthy that the majority of pre-service teachers (10 of 15) specifically mentioned that students should create and implement a plan. For the STEM lessons that the pre-service teachers taught prior to responding, all but one of the lessons consisted of students creating a plan, creating something and then testing it. This was not a requirement of the assignment, but rather an unexpected commonality among nearly all of the lessons taught. The instructors did not talk about this explicitly or model this structure in their lessons. One possible explanation for teachers thinking a STEM lesson should include creating a plan and creating something to try to solve a problem, which the teachers shared in their reflection about planning, is that the preservice teachers used the internet to get ideas for their lesson. Many of the STEM lesson ideas that are commonly found online include this structure.

Conclusions, Implications and Further Research

While nearly all pre-service teachers (14 of 15) initially knew that STEM was an acronym for Science, Technology, Engineering and Mathematics, preservice teachers were unclear about how to teach it. When asked to give an example of a STEM lesson they had seen or taught before, one-third of the students said they had never seen a STEM lesson and the remaining students gave examples of lessons they had seen or taught in a science or math classroom observation, but their explanation of why it was STEM showed their limited understanding of the need for integration in STEM.

After the midpoint survey, 11 students referenced those lessons as examples of STEM lessons they had seen or taught. Interestingly, three students cited lessons they had previously taught for their math or science methods course, which had no expectation or requirement for STEM. Their lessons did not integrate any of the other subjects, but these preservice teachers tried to retrofit the other disciplines into the lesson for example, “I used a video which is technology, and engineering when students drew 3D shapes.”

In the post survey, preservice teachers’ response to: What is STEM? In addition to stating the four disciplines, student definitions included integration (9 of 15), hands-on (7 of 15), and student centered (6 of 15), real-world (4 of 15). Interestingly, nine of the 15 preservice teachers also included a specific number of subjects that should be included to be considered STEM, ranging from 2 to all 4, with 3 teachers including that 4 out of 4 disciplines would be preferred or the best scenario.
Implications

STEM Education is the wave of the future, with funding, public interest, and renewed interest in career readiness serving as driving forces. Through careful planning and collaboration, including opportunities for preservice teachers to learn about and practice writing and teaching STEM lessons, students were applying already established best practices for instruction, such as writing objectives that had appropriate assessments, considering and planning for differentiation, developing learning activities aligned to standards, planning key higher-order thinking questions and reflecting on student work and ideas.

References


DIALOGIC TEACHING AS A TOOL FOR DEVELOPING REASONING SKILLS IN ETHIOPIAN PHYSICS EDUCATION

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This study draws on a socio-cultural definition of scientific reasoning with the aim of developing the reasoning skills Ethiopian pre-service teachers through dialogic teaching. A 5-day training on scientific argumentation and dialogic teaching was given to 11 lecturers from six Colleges of Teacher Education. The research questions were in what ways the intervention changed classroom teaching and what effects were made on students’ reasoning skills. Six lecturers made a control group. A total of 34 video-recorded lesson observations were made with each lesson followed by video recording of 3-5 pre-service teachers engaged in argumentation tasks. Lessons and group tasks were transcribed and analysed in NVivo. Students’ reasoning skills were measured in a pre- and post-test. The outcome showed significant differences between the experimental and control groups in both the teaching methods and student progression on the reasoning test. Lecturers’ ability to implement dialogic teaching was classified at three levels, which seem to influence the learning outcome of the pre-service teacher candidates. A way forward is improving the training programme to enhance the quality and skill of teaching to the highest level.

INTRODUCTION

Actual classroom practices in Ethiopian Education are dominated by didactic pedagogy with large class sizes and teacher qualifications being the most critical factors (Frost & Little, 2014). This classroom environment stands against harnessing the power of student talk to stimulate dialog and developing their scientific reasoning skills through engaging in socio-cultural types of interactions (Vygotsky, 1978). What helps, rather, is changing the pedagogy towards dialogic teaching and providing students with tasks that stimulate scientific argumentation (Driver, Newton, & Osborne, 2000) and reasoning skills (Kind & Osborne, 2017). One way is trying this strategy in pre-service teacher education in Ethiopia. The paper asks two research questions. Firstly, in what ways did the intervention change the pedagogy of physics teaching in the teacher education, and secondly, what effects did the change have on pre-service teachers’ reasoning skills?

LITERATURE REVIEW

The current study draws on disciplinary dialogic teaching, which merges dialogic teaching with socio-cultural learning theory (Vygotsky, Bakhtin, Wertsch etc.) and informal argumentation as practiced by scientists. Robin Alexander (2008) has elaborated the use of dialogic teaching across school
subjects and Vygotskians claim that knowledge and skills exist in the social culture and are internalised by students through language and use of tools. Dialogic teaching establishes explorative talk (Alexander, 2008), which makes students’ ideas explicit to help them improve their understanding of scientific concepts.

The idea of science as a pure empirical-logical activity is rejected in favour of informal argumentation where scientists put ideas and evidence forward for debate rather than proving claims with absolute certainty. Science educators have adopted this perspective and merged it with socio-cultural learning to form a strand of research and teaching known as scientific argumentation. In scientific argumentation, focus is on accountable talk (Michaels, O’Connor, & Resnick, 2008), which follows norms and criteria established in the science community. Dialogic teaching in science should, therefore, reflect the cultural ways of arguing that is typical to science.

The current study takes this combined perspective one step further by adding Crombie’s (1994) styles of reasoning. The rationale is to bring together the external (dialog) and the internal (cognitive) perspectives. Since physics is the focus of this study, only three of the six styles of reasoning have been selected: mathematical-deductive reasoning, hypothetical model-based reasoning, and experimental reasoning. Disciplinary dialogic teaching should therefore be implemented through scaffolding activities to reflect each of these styles, so that students can argue and internalise ideas.

THEORETICAL FRAMEWORK

The current study regards scientific reasoning as a cultural phenomenon based on cognitive history (Crombie, 1994; Netz, 1999) and focuses on three styles of reasoning, which are obvious targets in the physics curriculum: mathematical-deductive reasoning, hypothetical model-based reasoning and experimental reasoning. Kind and Osborne (2017) have suggested that to learn these types of reasoning, students must understand conceptual, procedural and epistemic knowledge. An intervention should elicit these types of knowledge in student discussion tasks (scaffolding tasks) and help students practice reasoning through dialog. A proficiency framework (Ford & Wargo, 2012) indicates progression in students’ learning via, first, recounting basic elements of the reasoning, second, being able to apply the reasoning in solving problems, third, juxtaposing alternatives within the reasoning, and fourth, critiquing the reasoning.

METHODOLOGY

Eleven (male) lecturers from six Colleges of Teacher Education (CTEs) were given a 5-day training about dialogic teaching, scientific reasoning and argumentation, and how small group and whole class discussions could be organised using scaffolding tasks. Examples focused on the three styles of reasoning and four progression levels mentioned above. After training, the lecturers developed discussion tasks to be implemented in the teaching over one academic year.
The study used a quasi-experimental design with experimental and control groups. The experimental group included 11 lecturers who took the training and 328 pre-service teachers and the control group had six lecturers and 108 pre-service teachers from four matching CTEs. Data gathering included a pre- and post- reasoning test and two video-recorded classroom observations of all 17 lecturers. Right after each video-observed lesson, one group of 3-5 pre-service teachers was given an (about 45 minutes) argumentation activity to analyse the quality of their scientific argumentation. Pre- and post-testing was analysed in SPSS using ANOVA. Video-observations were transcribed, translated into English and analysed in the software NVivo. Classroom videos were coded for amount of time spent on student-led versus teacher-led teaching in groups and on whole class discussions, and also for quality of teacher utterances to student groups and the class in discussions. Group-task recordings were coded with a scheme for quality of scientific argumentation (Erduran, Simon, & Osborne, 2004).

**FINDINGS**

One finding is the sharp contrast between teaching methods. Lecturers in the experimental group spent 80-90% of the teaching time on group discussions, while in control group this was typically 10% or less. Experimental groups, however, vary in their dialogic pedagogy with three hierarchical levels. The lowest level allowed student talk by organising group tasks. The next level gave students relevant and meaningful discussion tasks and guidance, but the quality of these varied with having germane conceptual, procedural and epistemic ideas and also on how clearly the lecturers helped students structure the group discussions. At the third level lecturers helped students summarise discussion points in whole-class discussions, but again with much variation in quality. Some lecturers turned this summary into didactic lecture disregarding students’ arguments and viewpoints. Other lecturers started whole-class summary by asking groups about their arguments and conclusions. Similar evaluation could not be used in the control group for lack of student discussion, but there were observed variations regarding ability to adjust pace and content of teaching to students’ level of knowledge.

The group tasks showed overall improvement from first to second recording. Towards the end of the academic year, pre-service teachers provided scientific debates with higher scores in the argumentation framework. We also observed higher quality argumentation in experimental groups than in control groups.

The pre- and post-tests showed overall positive significant progression (p < 0.05) for the experimental group, but not for the control group. Change of pedagogy improved reasoning skills, but with much variation between the classes. Partial analysis of data indicates that the hierarchical levels mentioned above correlate with pre-service teachers reasoning scores.

**CONCLUSIONS**
This study asked if a change from didactic to dialogic pedagogy in physics teaching will improve pre-service teachers’ reasoning skills. The outcome is positive, but with warnings that dialogic teaching has to fulfil certain requirements. The dialog has to be highly structured and much depends on teachers’ ability to organise group and whole-class discussions. The findings suggest that moving towards dialogic pedagogy may be one way of combating low performance levels in physics education. Further research should investigate ways of making lecturers more proficient at handling the new pedagogy.

REFERENCES

ADAPTION OF AN INSTRUMENT TO MEASURE LEARNERS INTEREST IN SCIENCE THROUGH PARTICIPATION IN A CITIZEN SCIENCE PROJECT
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Abstract
The study adapted an instrument used to measure participants’ interest in science developed by a research group from The Cornell Lab of Ornithology situated in USA. The USA research developed a set of instruments aimed at measuring outcomes such as interest, motivation, self- efficiency and skills. These instruments were made available on request with the aims of piloting them so the necessary changes could be made based on feedback. Initial stages involved analysing the questionnaire before piloting. Changes were made to statements on the initial instrument as they were biology biased. Since the current study seeks to assess interest in science in general as opposed to biology alone, these changes were necessary. Upon piloting the instrument, small changes were made in terms of the LIKERT scale. Changes included changing the 5-point scale to a 4-point scale and adding questions to test whether participants were reading the statements on the instrument. The final instrument was found to be more suited for the purposes of the project.

Introduction
Citizen science is an informal learning approach that is expanding. The term citizen science has even gone so far as to be included in the Oxford English Dictionary in June 2014. There are different types of citizen science projects, but it is an accepted notion that citizen science involves a set of volunteers that actively engage in real scientific research that focus on real world issues (Cooper, Dickinson, Phillips, & Bonney, 2007; Wiggins & Crowston, 2011). This is the definition I have used for my research when referring to citizen science. The different types of citizen science projects include public participation in scientific research (Bonney et al., 2009), public participation in community based monitoring (Conrad & Hilchey, 2011; Fernandez-Gimenez, Ballard, & Sturtevant, 2008), and collaborative monitoring (Fernandez-Gimenez et al., 2008).

Each project comes with its own set of goals and outcomes. For my research study, the type of citizen science project that will be undertaken is collaborative monitoring; a type of citizen science project where the scientist comes up with a research question and the volunteers collect data to answer the scientist’s research question. This study focuses on the following research question:

What impact does participation in an online citizen science project have on learners’ interest in science?
Literature Review

On a daily basis, more citizen science projects are becoming available online so that an increasing number of people are able to access these projects.

There is a website called sci-starter that has a list of over 600 citizen science projects which are put into different topics (Malykhina, 2013). The website has the added benefit that the citizen science projects are listed according to subject area. This assists visitors to the website to quickly access citizen science projects in topics of their interest.

Technology plays a major role in the popularity of citizen science projects. Volunteers have the option of using the internet to seek out projects in topics that they are passionate about and in the process learn more about their topic of interest (Bonney et al., 2014).

Also, with the development of mobile applications, wireless sensor monitors and online computer and video gaming, interests are sure to arise amongst volunteers as volunteers would be able to have fun, and also find easier ways by means of technology and training in that technology to collect the relevant data accurately (Malykhina, 2013; Newman et al., 2012; Soniak, 2012).

For my study, I have chosen a citizen science project which did not take into consideration any interests learners have in a particular topic. Since there is little evidence of school learners in South Africa actively being involved in citizen science projects, it would be noteworthy to determine whether by exposing learners to a citizen science project, it would increase learners’ interest in science and citizen science projects.

Theoretical Framework

The study is rooted in constructivism, and Kolb’s theory of experiential learning is used as a model to interpret the outcomes of the study. Below is a summary of this model:

![Kolb's Cycle of Experiential Learning](image-url)
The meaning of the stages is summarised below:

- **Concrete Experience**: An individual is assigned a task that requires active involvement.
- **Reflective Observation**: Individuals are required to review what they did or experienced.
- **Abstract Conceptualisation**: The individual makes comparisons with what they have done, and also reflect on what they know.
- **Active Experimentation**: The individual put what they have learnt into practice.

**Methodology**

19 Learners from a high school in Gauteng formed the pilot group for the study. An instrument measuring interest in science was given to the leaners to complete, after they had completed the set of activities from the selected citizen science project.

**Findings**

The table 1 below shows the statements learners responded to:

<table>
<thead>
<tr>
<th>Statement No</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>I want to learn more about the sciences (e.g. Chemistry, Physics, Biology).</td>
</tr>
<tr>
<td>S2</td>
<td>I like to engage in science-related hobbies in my free time.</td>
</tr>
<tr>
<td>S3</td>
<td>I want to understand how processes in nature work (e.g. how birds migrate, why leaves change colour, how bees make honey, etc).</td>
</tr>
<tr>
<td>S4</td>
<td>I often visit science-related web sites.</td>
</tr>
<tr>
<td>S5</td>
<td>I enjoy learning about new scientific discoveries or inventions.</td>
</tr>
<tr>
<td>S6</td>
<td>Other people would describe me as a &quot;science person.&quot;</td>
</tr>
<tr>
<td>S7</td>
<td>I enjoy reading about science-related topics.</td>
</tr>
<tr>
<td>S8</td>
<td>I like to observe birds, butterflies, bugs, or other things in nature.</td>
</tr>
<tr>
<td>S9</td>
<td>I enjoy talking about science topics with others.</td>
</tr>
<tr>
<td>S10</td>
<td>I am interested in learning more about the physical sciences (chemistry, physics, astronomy, and geology).</td>
</tr>
<tr>
<td>S11</td>
<td>I enjoy looking at information presented in scientific tables and graphs.</td>
</tr>
</tbody>
</table>

The questionnaire used a 5-point LIKERT scale with the scores indicated in Figure 2 below:

<table>
<thead>
<tr>
<th>Strongly Disagree (1)</th>
<th>Disagree (2)</th>
<th>Neutral (3)</th>
<th>Agree (4)</th>
<th>Strongly Agree (5)</th>
</tr>
</thead>
</table>

*Figure 2: Likert Scale used in study*

Since the learners were involved in a Geo-Science club, it was expected that the outcomes in terms of averages would be between 4 and 5, as participation in the club would suggest a great interest in issues relating to the sciences.
Taking a closer look at the outcomes of the questionnaire, this was not the case for all the statements. 4 out of the 11 statements had averages of 3. Below is a graph that summarises the averages per statement:

![Graph Showing Averages Per Statement](image)

*Figure 3: Averages per statement*

The results suggest two important questions:

1. Are there problems with the phrasing of the 4 statements?
2. Is there a problem with the Likert scale that would bring about the averages seen?

These are two important factors to consider when looking at the pilot questionnaire. For the purpose of the larger study, only one factor was changed. Since the averages were sitting at exactly 3, I looked at the number of occurrences that learners chose the Neutral column. Below in Table 2 is a summary of these occurrences:

<table>
<thead>
<tr>
<th>Statement</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2</td>
<td>9</td>
</tr>
<tr>
<td>S4</td>
<td>6</td>
</tr>
<tr>
<td>S6</td>
<td>6</td>
</tr>
<tr>
<td>S11</td>
<td>6</td>
</tr>
</tbody>
</table>

*Table 2: Frequency Table showing Tally of Neutral Choices on 4 Statements by Learners:

Table 2 shows that the neutral column does affect outcomes. This led to eliminating the neutral column from the Likert scale.

**Conclusion**

The current instrument formulated by the Lab of Ornithology is problematic, and changes made were needed to better measure learners’ interest in science.
References


WHAT DOES A STUDENT CAREER EXPLORATION SHEET REVEAL ABOUT STUDENTS’ STEM CAREER PATHWAYS?
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¹North Carolina State University; ²William and Mary
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Abstract
The Student Career Exploration Sheet (SCES) was developed based on constructs of Expectancy-Value Theory to elicit middle school students’ thinking about their futures. These students were strong in self-efficacy and ability beliefs, identified with becoming college students, but had few STEM experiences or role models, suggesting the usefulness of the SCES was useful in highlighting students’ strengths as well as gaps in career pathways.

Introduction
Middle school students are beginning to form an understanding about who they are, making this period of time ideal for studying how they incorporate information about STEM disciplines into their lives and futures (Tai et al., 2006). Many students, particularly underrepresented minorities and females, may be unable to see themselves in STEM careers (Russell & Atwater, 2005). Students’ consideration of career pathways may be influenced by a student’s identification of him/herself as a STEM person (Tan & Barton, 2008), being recognized by ‘important others’ as a member of the STEM community (Carlone & Johnson, 2007), access to and opportunities in STEM (Subotnik, Edminston, and Rayhack, 2007), personal ability beliefs and expectations of success (Bandura, 1986), and the values that one places on completing tasks and making academic and career related decisions (Eccles, 2009; Eccles & Wigfield, 1995).

Theoretical Framework
In Expectancy-Value Theory of Achievement Motivation (EVT; Eccles, 2009), people’s expectancies, ability beliefs, and values directly affect choices, performance, effort, and achievement. Other influences are socializers (e.g., parents, teachers) and one’s interpretations of previous life experiences (see Figure 1). This theoretical framework was applied to develop the Student Career Exploration Sheet (Author, 2016) used for this study (see Methods).

Research Questions
When middle school students were given a choice of STEM career videos to explore:
1. What are students’ career explorations choices, and do they describe these choices as linked to their experiences or the careers of their families/friends?
2. What were students’ perceptions of the careers they explored and how it related to their goals and/or identity?
3. What were students’ expectations for success and planning to assist in that future success?

**Figure 1. Expectancy-Value Theory (EVT; based on Eccles, 2009).**

**Methods**

**Context and Participants**
This qualitative case study (Creswell, 2012) was part of a larger National Science Foundation grant that supported after-school STEM career clubs in low wealth, rural U.S. middle schools. We piloted the Student Career Exploration Sheets (SCES) (Author, 2016) with 48 rural middle school students who were a part of this project. The students were from 6th grade (22; 46%), 7th grade (16; 33%), and 8th grade (10; 21%). Students were mostly female (28; 58%), and African American (29; 60%).

**Data Collection and Analyses**
The Student Career Exploration Sheet (SCES; Author, 2016) was developed around constructs of Expectancy-Value Theory (EVT) to capture self-reported, qualitative data from students to understand more about how the students “tried on” the career aspects in relation to themselves (see Figure 2). Prior to watching a self-selected video clip (usually 5-10 minutes), students were asked to respond to the yellow portions of the sheet. Post video, students were asked to complete the rest of the sheet. Students’ responses were typed, verbatim, and imported into Atlas.ti and coded in two rounds of coding; first, using the students’ words and then, categorized for patterns across students.
Findings

RQ1: Career Choices and Links to Experiences or Family/Friends’ Careers

Video Choice
Overall, students were most likely to choose a Science Career (47.9%) followed by Technology (35.4%), Engineering (20.8%), and Mathematics (2%). Most females chose caring or helping careers, and most students (60.4%) said they related to the professional in the video most students (60.4%) citing a related interest or hobby, personal characteristics, shared experiences or skills.

Family and Experiences
Most students (54.2%) chose career videos that aligned with their experiences, hobbies or interests, or the STEM Club. Many students chose careers that did not relate to those of their family members (47%); fewer indicated that a family member had the same job (10.4%) or a related skill set (20.8%).

RQ2: Students’ Perceptions of the Careers Explored and Its Relation to Their Goals/Identity

Feelings
Students had overwhelmingly positive perceptions (e.g., “caring,” “cool,” “fun”) about people in the profession (72.9%) and predicted their family would be supportive (e.g., “happy,” “proud”) if they chose to pursue that career. Most students (66.7%) listed their career related skills, specific experiences, or academic behaviors that would make them better in the career. Students (56.2%)
provided general skills, academics, and soft skills (e.g., “caring,” “understanding people”) as things that make them well suited for the career.

**Goals/Identity**
With respect to future goals, most students (87.5%) planned to attend college, with a subset of these indicating advanced degrees (10.4%).

Many students described themselves using positive terms, including “smart,” “fun,” “nice,” and “goofy/funny,” “short,” “pretty.” Most thought their friends would also describe them positively, mixing in “bossy” and “obnoxious.”

**RQ3: Students’ Expectations and Planning for Success**

**Success**
The question, *What do you do that helps you to be successful?* resulted in many students (52.1%) mentioning academic things, such as getting good grades and paying attention. Quite a few students mentioned effort and determination (37.5%).

When asked about barriers to career success, fifteen students (31.3%) thought nothing could get in the way of success. One-third (33.3%) indicated that their choices and behaviors could get in the way. Family, outside influences, and cost were other concerns (37.5%).

Fears and career related stress accounted for 43.8% of the reasons they would not choose to pursue the career. Others listed changing their career choice (16.7%), family/self (10.4%), and low pay (6.2%) as career impediments. Interestingly, one-fourth (25%) of the students said nothing could stop them from pursuing the career.

**Spending Time**
Students were asked what activities they participate in outside of school, the top activity (37.5%) was participating in clubs or hobbies (33% of which listed STEM Club), followed by sports (33.3%).

The activities participate in at school included the STEM Club (85.4%), followed by academic and special interest clubs (39.6%), band/chorus (20.8%), and sports (12.5%). Students also listed other out-of-school activities such as church or community activities.

In terms of preparing for the chosen career, most students identified a career specific activity or practice, such as “I could take classes that involve...”

![Figure 3. Strengths and weaknesses identified by SCES.](image-url)
programming and robotics so I'll have some experience,” while others offered more general practices such as “studying hard.”

Conclusions & Next Steps

Overall, the SCES seemed to be useful in prompting students to think about themselves in relation to future careers (see Figure 3). As a group, these predominantly African American, rural STEM Club students were strong in self-efficacy and ability beliefs, identified with becoming college students, and believed they had the skills to be successful in school. However, the students had few out of school STEM experiences (other than the Club), few family STEM role models, and unclear goals for college attendance or potential majors. With more refinement, the SCES could provide a tool for guidance counselors, classroom teachers, educational researchers, and those who work in informal STEM Education settings.

References


EXPLORING THE POTENTIAL OF AFTER-SCHOOL STEM CLUBS WITH RURAL U.S. STUDENTS
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Figure 3. Strengths and weaknesses identified by SCES. (See previous paper)

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References

THE USE OF LANGUAGE TO EXPLAIN GENETIC CONCEPTS: Does it Matter in the Teaching and Learning of Genetics?

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Introduction

The art of teaching requires teachers to play different roles and among these, the way in which the teacher talks to and with the students in meeting their learning need is very important (Cian & Cook, 2018). Genetics is considered to be a fascinating but difficult topic to understand (Thorne, 2012). Many studies have associated this difficulty to issues of terminology with words such as gene, DNA and chromosomes, meiosis and mitosis, allele. These words and concepts are unique to genetics and are classified as technical words (Halliday & Martin, 1993) and are often confusing and hard to understand. According to Löbner (2002), a word has a sound when spoken and a spelling when written, but without describing it, it becomes difficult to know its meaning from just hearing and reading it. In this study, we refer to word as any combination of letters that constitute an entity in a text (Thorne, 2012: H). The many terms associated with genetics, some with almost similar sounds and different meanings as well as synonyms, seem to contribute to an even larger terminology and learning problems.

The importance to teach about the relationship between genetic terms and concepts is argued in the literature (Thorne, 2012; Venville & Treagust, 2002). In the teaching of genetics, if the meanings of technical terms and concepts are not clear, it can become frustrating to students prompting them to lose interest. The teaching of genetics makes demand on teachers to use language, orally, in print and in other forms of symbolic representations. Grossman (2011) and van Driel et al. (2002) outlined the discourse practices of an effective teacher, which involves awareness of the varied strategies available to respond to diverse classroom situations. In this study, we consider language to be at the very core of teaching as informed by Lemke’s conception of language as “system of resources for meaning making” (Lemke, 1990:11). Despite the importance of teacher talk as the medium for meaning making in the classroom, there is limited research that systematically investigates what actually goes on in the classrooms as compared to the many studies that focus on what to do in the classroom (Mortimer & Scott, 2003; Ogborn & Kress &Martins, 1996). The need for good explanations in classroom talk is emphasised in the literature (Ogborn, et al., 1996; Cian & Cook, 2018). It is for this reason that this study was carried out to investigate what is presented through teacher talk to students in the classroom when teaching genetic concepts, an area which is known to be crucial and problematic (Department of Basic Education (DBE), 2017) and the research question that guided our study is,
1. How is the teacher using language to teach genetics concepts?

The overarching aim of this study is to investigate how the lecturer is using language in teaching of genetic concepts in order document the findings. In pursuit of this aim, the study has the following objectives:

- **Research objective 1**: To identify what kinds of communicative patterns and the scientific meanings realised in the language used by the lecturer when teaching genetic concepts.
- **Research objective 4**: To document possible ways of addressing language issues associated with the teaching and learning of genetics.

**Theoretical framework**

In conceptualising the use of teacher language in the teaching of genetic concepts, this study draws from ideas related to Systematic Functional Linguistics (SFL) which is a theoretical framework for understanding how language functions in meaning making (Halliday, 1993; Halliday & Martin, 1993). The SFL informed Lemke’s work in 1990 where he referred to language as a system of resources for meaning making and argued that concepts make making only when used in conjunction with other concepts. In this study, we draw from Lemke’s ideas to explore a lecturer’s communicative approach in the teaching of genetic concepts in the classroom.

**Literature Review**

*Communicative approaches in Science Classrooms*

The teaching of science makes demand on teachers to use language in different forms including text, oral and symbolic representations. Many studies have reported the key role of language in learning and informing how we understand and make meaning of our world (Lemke, 1990; Mortimer & Scott, 2003; Seah, Clarke, & Hart, 2014). Lemke (1990) notes that understanding science as a discipline requires an awareness of the language practices that define the community of science. According to Lampert (1990) and van Zee et al. (2001), a teacher’s teaching approach has a direct influence on the type of discourse that can exist in the classroom. Literature on classroom interaction indicates that various types of questions can be used in classroom interaction based on purpose, form and function. In this study we focus on the function of the question asked by the lecturer in conjunction with explanations. Examining of the questions and explanations was done to establish if the teaching of concepts involved linking them with other words in creating scientific meaning as suggested by SFL framework (Thorne, Long & Sato, 1983) provide three types of questions in relation to function namely, comprehension check questions, confirmation check questions and clarification check questions. These ideas will inform how we understand the classroom interactions and the communicative practices used by the lecturer in teaching of genetic concepts.
Research design and Methodology

This study is predominantly qualitative. We decided to use the qualitative approach because we wanted to have a full picture of specific communication patterns in the teaching of certain genetic concepts. Therefore, in addition to video and textual analysis of the video recordings and transcript of the lectures, we conducted interviews which were led by the first author to sought answers from the second author to questions pertaining to her choice of communicative patterns used during classroom interaction with the students. To do all this, we took the ontological position that lecturers' perceptions form social realities (Mason, 2002), which we sought to explore in the context of this study. Mason (2002) further postulates that the legitimate way of generating data on such ontological perspectives, is to talk with the participant interactively.

The participants were one biology lecturer and her class of pre-service teachers. The lecturer who is the second author in this study was the presenter of the genetics course. The students became participants by virtue of them being registered for the course. Their consent was sought at the beginning of the course. It was explained to the students that while the focus of the research was the lecturer, their consent was required as the research will be taking place in the classroom. The SFL framework was used in coding the data to investigate how the teacher used language in teaching genetics.

Data collection and analysis

The genetics course is a six-week course of three teaching hours a week (one 2hrs session and one 1hr session). A total of six two hour and six-hour lectures were video-recorded. The following topics were covered: Genetics at molecular level, meiosis 1 and 2, Mendelian inheritance including both monohybrid and dihybrid inheritance, mutations and genetic diseases. This short paper is based on the analysis of three lectures during which the topics genetics at molecular level and meiosis were taught. These were also the first three lectures of the course. These lecturers were chosen as it was during these lectures that most of the difficult genetics’ terms were dealt with. The video-recordings of these lectures were firstly viewed by the two authors three times. The viewing was done so that the authors would become familiar with what transpired during the lectures in terms of communicative patterns?

Thereafter, the first author conducted semi-structured interviews with the second author guided by explicit questions about her choice of communication patterns. The interview data was transcribed by the first author while the audio part of the lecture videos was transcribed by the second author. Both authors had to check each other’s work. As such, the first author had to go through the lecture videos transcript while listening to the videos and the second author did same for the interview transcript. This was important and done to mitigate human error and to ensure accuracy of the transcribed data. Before we began coding the transcribed data, we systematically organised the information about participant to put the data in order. We organised the transcripts into files and
labelled each lecture according to the sequence in which it was recorded for example GL1 for the first lecture, GL 2 for second lecture.

**Coding of data**

In the next step of data analysis, we adopted skills offered by Content Analysis also termed conceptual or thematic analysis (Babbie & Rubin, 2007). We carefully read through the transcripts of the lectures and interview, made some notes and did minor editing. The aim was to thoroughly understand the content of the data and develop a sense of how the participant is using language in classroom interaction so we can understand the thematic patterns. After we had become familiar with the data, we started coding it by labelling units of meanings within the text and separating the text into manageable parts. The coding was informed by ideas relating to the SFL framework (where meanings of words are realised in the way words are used in conjunction to other words (Halliday & Matthiessen, 2004; Lemke, 1990) and by the research objectives which seek to identify what communicative patterns are used by the lecturer in teaching of genetic concepts. At this stage, we agreed to only identify those elements within the transcripts that were relevant to our research questions and objectives.

In analysing for communication patterns, we referred to instances of questioning and explanation. These two categories provided discrete information for a straightforward analysis and occurred frequently and could relatively be easily identified through the coding of transcriptions. Thereafter, we revised the themes and recoded several times to capture things we might not have noticed in the first coding and then proceeding to data interpretation. Henning, Van Rensburg, and Smit, (2004) refer to data interpretation as a process that involves the identification of ways in which emerging themes and sub themes, connections and contradictions fit together.

**A sample of the results**

Analysis of data in this study revealed several patterns of language such as oral, written text and symbolic representations and communicative patterns such as questioning and explanation that were used by the lecturer that appeared to be significant for realizing scientific meanings in the teaching of genetic concepts. It is important to indicate that because these communicative patterns appear to be used in conjunction to one another.

**Use of questions, explanations and objects in teaching genetic concepts**

The use of questions in explaining chromosomes and DNA

Questioning emerged as the communicative approach used by the lecturer in teaching the concepts of chromosomes and DNA as illustrated in the excerpt 1 below

**Excerpt 1**
In excerpt 1, the lecturer begins by alluding to the nature of genetic information and interaction of genes within an organism as the focus lesson and goes on to make reference to a string. She proceeds by asking a question regarding the string (line 6) and gives an explanation to set the context for understanding DNA and chromosome which are the concepts under discussion at this point (Lines 16-20). She further makes reference to the link between DNA and chromosomes by making use of the analogy of a loose and an organized string which is the real-life context of the students in creating scientific meaning. She explains that the string is made loose (line 9) but when it is to be sold, it is organized into a round ball (line 10) so that it is easier to transport and get it to where it should be. She then compared the loose string to DNA and the organized string to chromosomes to clarify the meaning between the two words (lines 23 and 24). According to Tsui (1995), teacher questioning plays a special role by boosting classroom interaction through the stimulation of students toward the content elements. The content in this study is based on terminology in genetics.

Excerpt 2 below presents another instance where the lecturer uses explanation in clarifying the meaning between DNA and chromosomes as illustrated below

| Teacher | 1And so all those things are part of genetics. And so today our focus is 2this. So in this box..... They highlighted the information. Right, any 3questions so far? So this is what we are going to cover in the genetics 4course, the nature of genetic information. How the genes are transferred 5from cell to cell, and then how do the genes interact within an organism. 6Right. I have here this, what is this? |
| Learner | String. |
| Teacher | 7String. This is string. This is string. What is the difference between the two? |
| Learner | This one it’s stronger, the way it’s been organised, arranged, is stronger than that one, (?) |
| Teacher | 8He says the way it is organised makes it stronger. Right, when this 9string is formed it will be like this, and then before it is distributed or 10sold, or packaged, it is organised into a ball. Why is it important to put 11it into a ball instead of just actually selling it like this? |
| Learner | ...easier to maybe use it to make things...I know what you’re speaking about but I can’t... |
| Teacher | 13Ja, she’s saying maybe it’s easier to use it and to make things when it’s 14like this instead of like this. If you transport it like this, let’s say from 15the factory to selling points, what do you think will happen? |
| Learner | It will wind it around. |
| Teacher | 16It will get tangled. So that’s why one of the reasons why they have to 17form balls. Apart from that, if I am to throw this to someone, it will 18be easier to just throw like this, but this one it will be very difficult 19if it’s like this to get it to where I want it to go. Right. So if I say, this 20represents DNA in a cell, and that represents a chromosome. So what 21will be the difference between DNA and a chromosome? Think about 22it. I’m saying this as it is, loose after it is made represents DNA in a 23cell. And that ball represents a chromosome, also in a 24cell. So what is 25the difference between DNA and a chromosome? What are the similarities between DNA and a chromosome? Yes? |
The lecturer explains (line 1) that DNA are organised into chromosomes during cell division and she goes on to explain (line 2) the reason by stating that DNA is organised into chromosomes which is to facilitate and to ensure that it does not tangle in the process of transfer. In using both words and showing how link between the two, can help the teacher establish the meaning of DNA and chromosomes. This is in line with the ideas that meaning of words are realised when used in relation to one another (Halliday & Matthiessen, 2004).

**Use of questions in explaining DNA and gene**

The lecturer compares the DNA to a string in her explanation and uses questions to test students’ memory in defining gene in relation to DNA as illustrated in the excerpt below.

**Excerpt 4**

1 Okay, now, if I come to this now, this is still a string and
2 I’m saying it’s DNA, and the different coloured sections represent genes, 3 how would you define a gene?
4 Right, so this is DNA and the different sections, the brown, the white, the
5 different sections represent genes. So how will you define a gene? Yes?
6 Now can you think of the relationship then between DNA and genes?
7 Both answers are correct. But now if we look at…if we take his definition to say it’s a section of a gene…of a DNA. Yes?

In excerpt 4, the lecturer used explanation and questioning in an interactive way in defining genes and connecting it to DNA (lines 3,5,6). She highlighted the defining features of DNA (line 4) before asking questions and this could stimulate students’ thoughts to construct their own meaning of genes in relation to the definition of DNA. With respect to the connection between gene and DNA,

**Use of image explaining group and population**

**Excerpt 5**

Now I want us to look at that picture. Don’t worry about the words and the description, just look at the picture and tell me what you can see? What do you think you can see? Yes?
Yes, anything else? Okay, so let’s look at the picture together. If you start from the top, that’s a group of people there, and you can see it’s a population.
The lecturer uses an image to support oral communication and this shows potential to help the students to attach meaning to a particular word e.g. by pointing at a group of people on the picture and saying: “that’s a group, it’s a population” will enable students to link the word population to a group.

Conclusion

The findings demonstrate the value in the teacher’s use of different language patterns including spoken, written text and symbols in teaching of genetics and the some of the strategies that teachers can use to address the problems associate with the use of language to talk about genetics in the classroom during teaching. Use of real life familiar objects like the string, image as well as explanation, questioning and creating connections between words to support the lecturer’s way of talking in the teaching of genetic concepts suggest that she is aware of the terminology issues associated with genetics in the classroom. Hence, the potential of these linguistic resources to help students to focus attention and to attach and enhance meaning to a particular word which could ultimately provide lasting solution to some of the language issues in teaching and learning of genetics.

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THE KNOWLEDGE OF LOCAL COMMUNITIES AND THE MECHANISMS OF ALLOCATION OF NAMES IN THE DISTRICT OF MAGUDE - PROVINCE OF MAPUTO

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ABSTRACT

The present research fits the topic of education, in particular with regard to indigenous knowledge. This article is the result of a research that the Center of Studies of Educational Policies of the Pedagogical University of Mozambique has been developing for about six years. Our intention was to listen to what mechanisms are involved in naming. For this research, we only focus on the attribution of cattle names and newborn children. Thus, based on a qualitative research, in the case with ethnography and with the use of ethnomethodology, we investigated the communities of Motaze, having privileged opinion holders, such as community leaders, religious leaders, healers and parents and caregivers. Our starting question was, what mechanisms (social, cultural and anthropological) are imbued with naming cattle and newborn children? What educational didactic function is behind the attribution of these names? Would there be any linguistic function in this action? What moral and social authority does the person have and who can and should assign these names in this community? We conclude that there are socio-cultural and anthropological elements that underlie the mechanisms of naming in these local communities, elements that are present in the local knowledge of these communities.

Keywords: Local Knowledge; School Knowledge; Didactics; Name attribution; Maputo; Mozambique

INTRODUCTION

This research has as its core the community of Motaze, which is in the District of Magude, North of the Province. Here, our intention was to listen to what mechanisms are involved in naming. For this research, we only focus on the attribution of cattle names and newborn children. Thus, based on a qualitative research, in the case with ethnography and with the use of ethnomethodology, we investigated the communities of Motaze, having privileged opinion holders, such as community leaders, religious leaders, healers and parents and caregivers. Our starting question was, what mechanisms (social, cultural and anthropological) are imbued with naming cattle and newborn children? What educational didactic function is behind the attribution of these names? Would there be any linguistic function in this action? What moral and social authority does the person have and who can and should assign these names in this community? In the teaching and learning process, what curriculum should we design in our schools to accommodate such a phenomenon? From interviews and observation to this target population, we conclude that there are socio-cultural and
anthropological elements that underlie the mechanisms of naming in these local communities, elements that are present in the local knowledge of these communities. In addition, we find elements of didactic pedagogical cultural order in this action and that such appointment can only be made by elements that hold a certain authority in the local community. In terms of curriculum, there are elements in this mechanism of naming that can be transposed to the school knowledge. To this end, it is suggested to the makers of educational public policies that in the formation of teachers, there is room for the teacher to possess tools that allow him to get involved in the communities and from there to search for elements of local knowledge that can be validated and legitimized and transposed to the school knowledge.

So, in this research, we intend to achieve the following objectives: a) To gather the knowledge and cultural experiences that the local communities hold, related to the mechanisms of the indication of cattle names and to the newborn children, in the community of Motaze, district of Magude; b) To analyze the processes of production and legitimation of the local knowledge of this community, regarding the attribution of the name in bovine cattle and the newborn children; c) Suggest the possibilities of including the knowledge of local communities in school knowledge.

LITERATURE REVIEW/THEORETICAL FRAMEWORK

A study of local knowledge is of great importance because, on the one hand, the world orientation for education is the construction of knowledge that links the human being with his cultural environment. In this sense, the responsibility of education is to discover the cultural foundations of the students to reinforce the solidarity of the groups. On the other hand, responding to the calls of Jomtien (1990), according to which the development of the education of each country necessarily involves the rescue of local cultures, Mozambique introduced in the Basic Education the Local Curriculum, a component of the national curriculum that integrates aspects of local culture.

When looking at Mozambique, as a nation, a diversity of regions and ethnic-linguistic groups are contemplated which retrait not only geographical division, but also, with great emphasis and in equal proportion, a multiplicity of peoples with manifestations. These include philosophy of life, art, science, dance, music, language, religious rituals, contemplating a range of knowledge regarding the ways of being, living, doing and knowing the world that surrounds them become important in the formation of their peculiar socio-cultural identities, making them different from other peoples, both within and outside the country.

Thus, there are several authors who have been concerned with the study of local knowledge in Mozambique and its relation to school knowledge. Of these, the cases of CAPECE (2016), in his work "The rescue of the knowledge of the local communities: suggestions for the improvement of the teaching of Natural Sciences of the first degree, where he argues that the knowledge that the local communities have, when well systematized, can and should be appropriate and socialized for the official curriculum. That is, local knowledge has elements and has an intentionality that are of great
value and that can and should be rescued for school knowledge; CASTIANO (2011) arguing that the Local Curriculum favor the search of the communities' knowledge to be taught in school; Basílio (2013) with the argument, the curriculum must seek the cultural foundations of the students to reinforce solidarity and build the identities of the groups.

In Mozambique, studies on local knowledge are evident in the PCEB Curriculum Plan (2003), which is the result of the Curriculum Reform 2003/2007, where the Local Curriculum is described as the great innovation that brings the thesis that the students, starting from the Basic Education should be bearers of the local knowledge that are present in their communities and,

(...) For this, the school has at its disposal a time of 20% of the total time foreseen, for the introduction of local contents that they deem relevant (...) the proposed subjects for the Local Curriculum must be integrated in the different curricular subjects, which presupposes adequate planning of lotions. (PCEB, 2003: 27).

These positions conform to the ideals of FREIRE (1992) that supports the need to bring the knowledge of local communities to the process of teaching and learning, which goes through the observation of three fundamental steps namely: development of a research that the essential characteristics communities; and the role of the teacher as a mediating agent between these two types of knowledge. This is where CAPECE (2016) introduces the concept of tension between local knowledge and knowledge universal, and according to him, in this tension, what is seen is that the makers of public policies give greater priority to the universal knowledge at the expense of local knowledge.

This research arises to deconstruct this paradigm, with the defense of the thesis that, in the construction of school curricula, the local knowledge that is fruitful in the local communities must also be considered. That is why we went to the community of Motaze, Magude District, North of Maputo Province to learn about local (indigenous) knowledge that is mixed in naming these communities and how these knowledges can and should be incorporated into official curricula?

The above premises find their justification in the fact that the local knowledge crosses and is impregnated with the school knowledge. They communicate with school subjects becoming cross-cutting themes in the curriculum. The local knowledge here is understood as a set of knowledge, practices, attitudes, skills and experiences shared in the daily lives of the people of a given community.

From the relevance of the cultures, the reflections around the local knowledge and its articulation in the school began to dominate the two scopes: philosophical and educational. In the philosophical and educational scope because these intersect in the treatment of questions of knowledge. When they cross, they relate to the definition of national and local curricula. Philosophy intervenes to question the criteria of production and dissemination of knowledge, the nature and value of knowledge, and the kind of knowledge that the school tends to socialize in order to make student learning more relevant and effective. Education is concerned with designing curricula that are not only technical but also covering social and cultural spheres.
The above assumptions are based on the premise that the knowledge accumulated in mankind is the work of artisans who sew from their everyday experiences and are those cultural spaces and times that give meaning and meaning to their knowledge. The curriculum is a reflection of the participation of local handicrafts, in the dialogue between local cultures (interculturality) and between the areas of knowledge (interdisciplinarity).

From this diversity, we ask the following questions: What educational processes do we adopt, in order to reconcile this cultural, unscientific wealth and the need to build a national identity? Which way should the school go in order to become a place of coexistence and not a weakening of community relations and particularities? What knowledges have become relevant in shaping national, global identity without hurting local identities? In short, what curriculum for the Mozambican school to include this richness manifested by cultural diversity? These and other concerns are paramount in that it is intended to build a curriculum based on respect for indigenous cultures, local cultures rooted in multiculturalism.

To answer these and other questions we carry out the present research in Maputo Province, specifically in the district of Magude.

**METHODOLOGY**

1.1. *Bibliographic method*

With the purpose of taking ownership of the studies already done on local knowledge, this method aims to analyze sufficiently the materials and research publications inherent to the subject under study.

For GIL (1996) the bibliographical analysis aims to seek information about the study in the different secondary sources, while helping to clarify the probable zones of gloom around the subject. This research is developed from the material already elaborated, consisting mainly of books, periodicals, among other printed documents.

1.2. *Documentary method*

Depending on the research design, there is a range of non-personal documents that can be used in a survey, such as official texts, minutes, regulations, statistical data about a certain phenomenon, registration forms, evaluation sheets, student passbooks, among others.

BOGDAN & BIKLEN (1994) emphasize that documents are not only sources of information, but also social products that, from their analysis, can lead us to the understanding of a complex and sometimes complex set of phenomena that are interrelated and amenable to interpretation.
Documents as Law nº 4/83 of March 23 on the National System of Education, (SNE). National System of Education: General Lines and Law nº 4/83 and Curriculum Plan of Basic Education PCEB (2003), among others, were configured as relevant for the present research.

1.3. **Data collection techniques and tools**

1.3.1. **Interview**

For our research, since we were interested in collecting testimonials about the local communities' knowledge of naming mechanisms, this technique provided data on what the community of Motaze, Magude district "knows, believes or expects, feels or wishes, intends to do or did, as well as regarding their explanations or reasons for any of the preceding things (AMADO, 2013: 207).

For the materialization of this technique, we use as an instrument of data collection, the interview script. The interview guide is an instrument that the researcher prepared for the orientation of the conversation taking into account the objectives of the research. In this order of idea, AMADO (2013: 214),

(... ) Conceives the interview script as a structure consisting of thematic blocks and objectives. It is an instrument that helps to organize and manage the questions to be asked of the interviewees. These issues are the foreshadowing of what should be achieved in the data collection process and allows the researcher to systematize the information collected.

**ANALYSIS AND DISCUSSION OF RESULTS**

1.4. **On the mechanisms with regard to the appointment of bovine animals**

Regarding the name, the common census reminds us that regardless of whether it is common or proper, it serves to designate things, people, animals or places. From a linguistic point of view, the name, regardless of its morphology, function or functioning, is a linguistic accomplishment of variable fulfillment that oscillates between the word and the phrase pronounced, called, recited or evoked in the day to day.

Of course, although rarely in the day to day of the community, one cannot lose sight of the fact that the name can be written, readable or illegible. In fact, the name as a linguistic achievement, materializes a certain living language. Note that the same thing, the same person, the same animal or the same place can be assigned multiple names which in turn materialize several languages. This observation leads us to emphasize that there is a certain parallelism between the plurality of names

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9 For reasons of economy of space do not insert here the above script.
10 Objects, products, phenomena, events ...
11 Living or dead, real or imaginary, ...
12 Domestic or wild, real or imagined...
13 Real or imagined. ....
14 As Word, can be a simple word or a compound word.
15 Such is the case of the names of people whose main function is to legitimize or validate a document (cheque, certified, certificate, Diploma, dispatch, Decalcarão ).
polynomial), the plurality\textsuperscript{16} of languages (multilingualism\textsuperscript{17}) and the plurality of identities\textsuperscript{18} that are manifested in every social interaction.

From the anthropological point of view, it should be noted that the value or meaning of the names varies according to the context of use, the communication situation, the social actors involved and the moment in question. Curiously, the names are also subdivided according to the areas of knowledge, that is, popular knowledge and scientific knowledge. To illustrate this fact it is enough to remember that, to each popular name, corresponds a scientific name. So the bull for scientists is Bos Taurus, the cow is Bos Taurus Taurus, the dog is Canis Lupus Familiaris, the Lion is Panthera Leo\textsuperscript{15,19} and so on.

In our research on the functioning of local names in the Motaze community in the Magude district north of Maputo province, we questioned what mechanisms are involved in the intricacies of naming cattle? From the various answers we have systematized, we realize that naming is far from a simple act of naming. On the contrary, the act of naming is part of a rather complex, rich and astute dynamic. As regards bovine cattle names, for example, there is a taxonomic classification which, considering the similarity and dissimilarity of bovine characteristics, groups them into specific categories, that is, functional names known as "Lungazana" (light brown), as shown in the figure below:

![Figure 1: Lungazana (light brown)](image)

This designation is attributed to the ox whose skin appearance is predominantly light brown. If the predominant tone is of black spots interspersed with whites, it is called "Lhafukazi", the specimen of which is as follows:

\textsuperscript{16} In the case of people, we can highlight the official name, the traditional name, the name of childhood, adolescence, name names, pseudonyms or nicknames. The same happens with the name of places and things.

\textsuperscript{17} In Africa, there are few people who speak a single language, regardless of their status. In fact, these same languages have their names whose criteria of attribution are quite complex and even controversial. Thus, the difference between language and dialect is both ideological (official languages and vernacular languages) and scientific (language and variety of language).

\textsuperscript{18} The plurality of identity refers us to ethnicity, religion, national origin, sex, age, profession and condensed in the same being, i.e. the different sociological variables that define the profile of each social actor

\textsuperscript{19} Source: http://www.todabiologia.com/zoologia/nomes_animais.htm (4/7/2017)
Figure 2: Lhavukazi (white and black spots)
And when it has white and red spots, it is called "Nhokazi".

Figure 3: Nhokazi (white and red spots)

Also, when the black tone is brightened, it is called "Ntchilove".

Figure 4: Ntchilove (bright dark black)
And if the predominance of the color is a dark brown, the animal receives the local name of "Zotho", like the one shown below:

Figure 5: Zotho (dark brown)
As can be seen from an anthropological point of view, as a language, both popular names as well as scientific names designate, determine, classify, signify, communicate, transmit, finally, are endowed with power, knowledge and values that should not be hierarchically charged, since both have their epistemic legitimacy.

To deny this legitimacy is to promote "epistem- ity" that is currently called into question, because scientists seek to establish a dialogue and a bridge between knowledge of a different epistemic nature. But who assigns the name after all? Where does the name come from? We wanted to know. Here's what we've heard synthetically from local communities:

Regarding the attribution of names to cattle in the community of Motaze, Magude district, Maputo province, this depends on the most characteristic features of the animals and is also due to their physical size.

Our interlocutors have said that there is a freedom in this regard. However, the motivation varies from person to person. One of our interviewees mentioned that in assigning the names of herd he used other criteria than those mentioned above. He tells us that one of his animals is called "Carmona," which was his childhood name when he was a shepherd. Another report relates to an episode of a gentleman who has received money through compensation and with him has bought a herd of oxen. As a way of perpetuating the act, he attributed the name of the institution where he received the fund to one of the animals, in this case, it was named "Sekeka Motaze".

Another episode that was reported in relation to the intricacies that border the attribution of the names of the oxen was informed so by one of the interviewees: 

"(...) There are cases of the natives working in the "Rand" mines in neighboring South Africa. From there they bring large sums of money and invest locally. It turns out that one of the investments can be the cattle raising. To honor and perpetuate the act, they attribute the name of the "Mina" where they worked and they earned the money that later was invested in the purchase of the cattle to one of the animals, by the way the most esteemed one. They have revealed names such as "Harmony Gold", "Anglogold Ashanti", "Gold Fields Ltd", "Anglo American South Africa", and so forth.

Finally, there is a biunivocal relation between the name to be attributed to the animal and a concrete, real, visible, tangible action of the daily life of the local community.

This latter taxonomic designation, these same cattle bear both traditional or modern plurilingual anthroponyms of relatives or persons known within and outside the community (in particular, in the mines of South Africa) to immortalize them, either place-of-origin or areas where the inhabitants...
of the community passed, both names of mining companies, as we have said, where some members of the community worked.

It should be noted that here the bovine, without ceasing to be "Lhafukazi", "Nhokazi", "Nhokazi", "Ntchilove" or "Zotho", affirms itself as a language support to assume a specific social function, ie to honor someone as an anthroponym, to value a place as a toponym or to preserve the individual or collective memory as the name of the former mining company. Names as languages interpenetrate without distinction between anthroponyms, place names, common names, and proper names. This porosity of frontiers leads us to realize that, more than a simple animal, the bovine affirms itself as a school, a book, a library that preserves the memory of the community. That is why we argue that this type of message needs to permeate school knowledge, through a didactic and appropriate methodology. And for this to happen, it is necessary for public educational policy makers, to give priority to teacher training, a training that gives possibilities for the latter to contemplate the possibility of appropriation of the cultural and unscientific wealth that is present, sometimes in a form latent in these local communities. It's mine conviction that in the formation of educators there should be space for the creation of a methodology that will lead the educator to the "garimpo", in search of local knowledge in the communities, so that he is able to "apprehend" what exists of the universal in local knowledge, converting it into scholarly knowledge.

1.5. **On the mechanisms with regard to the appointment of newborn children**

What we have already reported in relation to the appointment of bovine cattle, is also extensive as regards the attribution of names to newborn children. On this subject, our interviewees asserted that each child usually has two names, one formal and the other traditional. The latter is assigned to the child after consultation with the ancestors. How does this happen? We inquired and the answer came as a surprise:

(…) When the baby cries frequently and interrupted and before the act, the family is worried and as a solution go to the healer in order to make consultation to know the reason for so much crying. There they are informed of the existence of an ancestor spirit who is "angry" at the fact that they have attributed a "strange" name to the child. To make this anger "disappear", the child is given the name that the spirit of the ancestor evoke, this in full session of the healer, after "beating" the magic stones. In these cases, the child is often given the name, first of a deceased of the maternal part and if this does not work, later it is used the name of a deceased of the paternal part.

Here is one of the episodes we have collected that highlights the web upon which the attribution of names to newborn children is woven:

When a child is born, it is possible to give the name of the father, the grandfather. In the old days, an appointment was made to see if the name assigned will "catch" or will not "catch", because sometimes the child became ill, he cried a lot; so the consultation was made and the question was whether it was the right name or not. If he took his name, the child would stop
Our partners in the community of Motaze, in the district of Magude, defend two scenarios involved in naming: The first scenario is preventive or meteorological and proceeds by anticipation before the "bitter" situation, seeking the right name through of consultations with the spirits of the ancestors; the second scenario, reactive, appears as a response to a problem detected, crying, illness, etc. The child could have two names: a "civilized" name and a traditional name. The first is used in the official register, in the school, in the workplace and the second is used in the family environment, in the community. When one goes to the consultation in the healer, it is this name that is evoked by this one that communicates between the person targeted and the ancestors.

But they also reported cases of humiliating and pejorative names attributed to children, especially when they are the result of illegal relationships. In these cases, they are given the names, for example, of "kwatine," which means "kill," or "thceleni," which means fifty cents to compare with something of low value; "Mbuene", to say that the child was born in the second house, "nwabjana", meaning something despicable, bad, comparing it to a dog, and so on.

Paradoxically, when it comes to sanctioning a serious offense, such as adultery for example, the anthroponym deliberately loses its human character to act as a sort of sentence for all life, not to humiliate the bearer of the name but to discipline the offender. In fact, as we saw earlier, a miner from the area betrayed by the woman who had a baby with another man decided to keep the marriage and not to part with it on the condition that he had the freedom to attribute the name of Kwatine to the newborn, changana, meaning woods, to designate a child made out of the house. Before the community and the offender, Kwatine functions as a bloodless reprisal. Here the name gains a performative dimension, since it is a form of acting. As we can see, the functioning of the name in the community is dynamic, methodical and complex. To paraphrase Saussure, who considers language as a social institution assimilated to a set of convections, it is no exaggeration to consider that the name is a social institution in the community and perhaps the main institution of the community.

Here it is reasonable to ask: what are the realities that are named? What are the social, cultural, political and economic implications of names? In Suma, what relationship exists between this "nomination" and the curriculum and what power is imbued with naming? The following text attempts to answer this.

**FINDINGS AND CONCLUSIONS**

From the testimonies of the local communities that are the subject of this research, especially in the community of Motaze, Magude District, north of Maputo Province, we could conclude that these communities have their own mechanisms of naming cattle, - born.
In relation to cattle, there are two forms of naming, the first being based on the color that predominates in the animal and the second based on the tendency to perpetuate the name of the Rand land mine, where the present breeder was a worker in neighboring South Africa.

Regarding the attribution of names to newborn children, we also find two situations: one that gives priority to anthropological questions, where the connection between the baby and the ancestors is fundamental. It is here that we witness the cases in which the child, who is initially given a name in which his ancestors do not "agree", has constant cries or suffers from a prolonged illness.

Either the first situation or the second, the problem is solved by consulting a healer. This one, after "talking", with the spirits related to the ancestors of the child, is that the name is attributed to him.

It should be stressed that this is not the official name. The child has a name, official, of the register and has the other, of the community and it is with this second that it communicates with its ancestors. When you go to the healer, it is this name that is evoked and not the official one.

In the attribution of names to newborn children there is also the pejorative side, where this child is the result of a relation less recommended by the local communities.

In either case, it is not a member of the community who assigns the names: it must be a member imbued with a symbolic power in the community, that unimpeachable figure who holds an unquestionable respect in the community. As a general rule, this person is the link between the community and the ancestors, and it is there that the community consults in case any malice disrupts the normal life of society.

We have also seen that in this naming exercise, there are elements of school knowledge that can and should be rescued. This is because this practice in the community is in disuse, being only held by older people in the community. Being in disuse, we must find platforms, especially in the so-called hidden curriculum, of how these themes can be safeguards in the classroom with the use of interdisciplinarity and transversal themes. This is because we recognize that there are educational elements in these practices.

On the other hand, from the analysis to the statements of our deponents and from an ethnomethodological approach of ethnographic character, we find that there are cultural and curricular elements that are, in a latent way in these communities. These knowledges that local communities hold, when well systematized, can and should be appropriate and socialized for scholarly knowledge since such knowledge has elements and intentions that are of great value.5.

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IMPACT OF PBGI INSTRUCTION ON CHEMISTRY TEACHING ASSISTANTS’ PEDAGOGICAL ORIENTATIONS AND CONCEPTIONS OF SCIENCE TEACHING

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Abstract
This study is on chemistry teaching assistants’ (TAs) pedagogical orientations towards science teaching and their conceptions of science teaching and learning before and after receiving instruction on inquiry. The study also investigated the relationship between TAs’ pedagogical orientations and their conceptions of science teaching after the intervention. TAs received instruction on inquiry through one-week summer workshop, and College Science Teaching Course offered during the academic year. Data was collected using Conceptions of Science Teaching and Learning Survey, and Pedagogy of Science Teaching Test. Results show TAs developed positive conceptions of science teaching and learning, and their pedagogical orientation moved towards inquiry instruction after the intervention. There was a significant correlation between TAs’ change in their conceptions in science teaching and learning, and change in their pedagogical orientations. Results have implications for chemistry instruction at college level.

Background
Research shows that most undergraduate science laboratory courses do not engage students in authentic scientific practices (e.g. Lord & Orkwiszewski, 2006). Such instructional strategies lead to students’ poor experience in introductory college science lab courses and low student retention in science degree programs (Ryker & McConnell, 2014). Our university is facing a similar problem in undergraduate science laboratory courses. In response to this problem, the National Research Council [NRC] (2012) suggests improving student learning in undergraduate science laboratory courses through inquiry-based instruction, where students engage in scientifically oriented questions, give priority to evidence, formulate explanations from evidence, connect explanations to scientific knowledge, and communicate and justify their explanations. Likewise, our National Science Foundation (NSF) Improving Undergraduate Science Education (IUSE) funded project has developed and implemented project-based guided inquiry (PBGI) labs in general chemistry laboratory courses. In a PBGI lab, students are provided with a problem and investigative question(s) they must solve over time and develop the method of answering the question, drawing their own conclusions, and communicating their results to instructors and peers. One of the objectives of our NSF IUSE project is to develop TAs’ positive conceptions of science teaching and pedagogical orientations toward inquiry instruction. We believe that the success of PBGI labs in our undergraduate chemistry lab courses will largely depend on the TAs’ positive conceptions of science teaching and learning and
their pedagogical orientations towards inquiry. This study addressed three research questions: What is the effect of a year long professional development (PD) on inquiry on TAs’ conceptions of science teaching, and pedagogical orientation towards inquiry instruction? What is the relationship between TAs’ change in conceptions of science teaching and their pedagogical orientations after PD on inquiry?

**Theoretical Framework**

Ramnarain and Schuster’s (2014) framework was used to assessing TAs pedagogical orientations towards science teaching. The framework has four teaching orientations namely; *didactic direct, active direct, guided inquiry and open inquiry*. In didactic direct instruction, an instructor presents a science concept or principle directly and explains it, illustrates with an example or demonstration. Active direct instruction is the same as the didactic direct instruction, but this is followed by a student activity based on the science concept being taught (e.g., hands-on activity verifying that the rate of a chemical reaction depends on temperature, concentration and surface area). In guided inquiry instruction, students are given opportunity to explore a scientific phenomenon or idea, with the instructor guiding them towards the desired concept(s) or principle(s) arising from the activity. In open inquiry instruction, students are free to explore a phenomenon or idea they wish to learn more. The instructor facilitates but does not prescribe or give out detailed procedures and answers. This framework was used to assess TAs’ pedagogical orientations towards chemistry teaching before and after PD on inquiry.

**Intervention**

TAs received instruction on inquiry through a one-week summer workshop, and *College Science Teaching Course* that was offered during the academic year. In summer workshop, TAs were introduced to PBGI labs, and performed the PBGI labs they were assigned to teach during the year. In the course, instructors modeled inquiry activities that addressed the five essential features of inquiry (*Question, Evidence, Explanation, Connect, and Communication*). TAs analyzed previous general chemistry labs for coverage of the five essential features of inquiry and made suggestions on how to convert them into full inquiry chemistry labs. Then, TAs developed PBGI chemistry labs that addressed the five essential features of inquiry and inquiry levels. TAs shared their PBGI chemistry labs with instructors and peers, and revised them based on the feedback. The task of developing PBGI chemistry labs was aimed at empowering TAs with skills for developing inquiry labs, to enhance their understanding of inquiry labs, and take ownership. We also believe that one way to improve science education for undergraduates is to engage TAs in developing inquiry labs so they will be able to develop their own labs when they become instructors after their graduate studies. TAs taught PBGI labs in general chemistry lab courses, and discussion sections during the academic year.

**Methodology**


A sample comprised 41 chemistry TAs at a research university. TAs had no formal training in science teaching prior to PD on inquiry instruction. TAs’ conceptions of science teaching and learning were collected through a 28-item survey, at a 5-point Likert scale from strongly disagree (1) to strongly agree (5). We used 8-item Pedagogy of Science Teaching Test to assess TAs pedagogical orientations towards inquiry. We adopted and modified test items from Schuster et al. (2012) to assess TAs’ pedagogical orientations towards inquiry chemistry instruction at college level. The items depict actual scenarios for teaching chemical concepts (Volume, Boyle’s law, Temperature and solubility, Atomic model, Air is matter, Thermometers, and characteristics of water) and provide four alternative teaching method options. Each item has a typical teaching vignette (that has realistic classroom situation, instructional goal, concept, facet of chemistry, phase of the lesson, and one main issue), question about possible pedagogy for the situation, and teaching options (four alternative approaches or comments in teaching approaches). The response options reflect four instructional types, namely, didactic direct, active direct, guided inquiry and open inquiry. Quantitative techniques were used to analyze data.

Results

**Pre-posttests on conceptions of science teaching and learning**
A t-test revealed a significant difference ($t = 3.61$ $p = 0.003$) between TAs’ conceptions of science teaching and learning before and after the intervention. Post-test Mean ($M= 4.52$, $SD=0.63$) was higher than the pretest mean ($M= 3.01$, $SD = 0.46$). This result implies that TAs developed more positive conceptions of science teaching and learning after the intervention

**Pre-posttests on TA’s Pedagogical Orientations towards inquiry**
TAs’ initial pedagogical orientations distribution was in the following descending order: Active Direct (67.75%), Didactic Direct (20.74%), Guided Inquiry (8.83%), and Open inquiry (2.68%). After the intervention, TAs’ pedagogical orientations distribution was Guided Inquiry (73.0%), Open Inquiry (15.31%), Active Direct (9.25%) and Didactic Direct (2.15%). The results suggest that before intervention, most TAs believed in Active Direct instruction, and after intervention most TAs subscribed to Guided inquiry instruction. Then, a t-test was performed to compare mean values of TAs’ pedagogical orientations before and after intervention. Initial pedagogical orientation toward science teaching mean of the TAs was 2.3, 0.36 SD (responses centered on Active Direct), while the mean for TAs’ pedagogical orientations after the intervention was 3.05, 0.25 SD (responses centered on Guided inquiry). The difference between the pre-posttest means was statistically significant ($t = 1.682$, $p <0.05$) with effect size of 0.42.

**Relationship between TAs’ Conceptions of science teaching & Pedagogical orientation**
There was a positive correlation ($r = 0.73$, $p=0.001$) between TAs’ change in conceptions of science teaching, and change in their pedagogical orientation towards inquiry science teaching. This finding suggests that as TAs’ pedagogical orientations moved towards inquiry instruction they developed more positive conceptions of science teaching and learning.
Conclusions

TAs developed positive conceptions of science teaching and learning, and their pedagogical orientation moved towards inquiry after PD. A significant correlation was found between TAs’ conceptions in science teaching and learning, and their pedagogical orientations towards inquiry after intervention. These findings suggest that it that a sustained PD on inquiry can increase TAs positive views of science teaching and move them towards inquiry instruction.

References

EXAMINING SCIENCE PRE-SERVICE TEACHERS’ LEARNING PROCESSES: An
Explanatory Study on the Acceptability of the Self-regulated Learning Theory as a
Promoter of Conceptual Understanding and Equitable Quality Education

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Abstract
The aim of this study was to provide the current status of the Self-regulated learning constructs; motivation and learning strategies of pre-service teachers majoring in Physical Science education specialisation. The purpose was to identify gaps so as to contribute towards empowering new teachers with positive attitudes and skills necessary to meet the needs of the learners they will teach. This aim was met through conducting a multiple case study on pre-service teachers at a tertiary institution using a mixed methods approach within the pragmatic paradigm. Two types of data collection instruments (surveys and interviews) were used sequentially to collect quantitative and qualitative data respectively. It was found that positive motivation profiles and frequent use of cognitive learning strategies had a positive impact on the academic performance of successful science students. Majority of the participating students were found to lack use of metacognitive learning strategies and resource management strategies, which is a great cause for concern and possibly one of the main causes of the problems leading to superficial conceptual understanding and poor academic performance in South Africa. The findings of this study have a potential to inform instruction towards assisting the Universities produce Physical Science teachers who are motivated and who possess relevant teaching practices. It also has the potential to make a contribution towards the attainment of sustainable development goal number 4, which concerns ensuring inclusive and equitable quality education and promote lifelong learning opportunities for all, through empowering student teachers.

Background and Rationale

Academic achievement can be said to be the main measure of success in the South African education system, from both the political and the academic points of view. Academic performance in science subjects is however one of South Africa’s education system’s biggest challenge. The statistics reported by the Department of Education (DoE) over the past five years attest to this (33% in 2013 and 38% in 2016 of the grade 12 learners obtained less than 30% in Physical Sciences). It is important to note that it is not just the number of students that pass the subject that is of concern but also the quality of the results obtained by those learners that do obtain a matric pass (Equal education, 2017). Various factors contribute to this issue and various science education studies have been conducted to try and address such challenges. These include studies on assessment, the use of different
textbooks, teaching and teacher education e.t.c... (Malcolm & Alant, 2004). This study aims to contribute to such initiatives through a study guided by a theoretical framework adopted from a theory of learning referred to as Self-regulated learning (Srl).

**Problem Statement**

Lack of motivation and poor conceptual understanding have been identified as one of the contributing factors to poor performance in Physical Sciences (Zimmerman and Schunk, 2011; Muhammed, 2011). As a university student and as a student teacher I observed that many of my fellow students did not take learning for understanding seriously. They opted for learning strategies that lead to superficial understanding (like simple reading and memorizing). The goal was to get the required 50% exam mark. The problem with this is that students complete degrees without understanding content, leading to further challenges outlined below. When student teachers complete their pre-service training without understanding, they will tend to teach the content at a superficial level, resulting in learners not understanding that content. When students do not understand a concept, they in turn lack the motivation to study it, hence propagating the cycle of science teachers who are neither motivated nor with good conceptual understanding of the content they teach (Tinajero, Lemos, Araujo, Ferraces & Paramo, 2012). Universities should be producing science teachers who are motivated to teach, and possess teaching practices relevant to the current student needs.

**Literature Review**

In this section Srl is defined as a theory consisting of multiple constructs, then narrowed down to the constructs selected to meet the aims of this study.

According to Schraw, Crippen and Hartley (2006), Srl involves combining cognitive strategy use, metacognitive control, and motivational beliefs to achieve academic success. Whereas Zimmerman (2002) describes Srl as referring to self-generated thoughts, feelings and behaviours that are oriented to attaining goals. Shraw and Brooks (1999) identify the Srl aspects that play an important role to the extent to which students self-regulate their learning to be self-efficacy and the use of relevant learning strategies. The common idea amongst these descriptions is the combination of motivational aspects with the actions taken by individuals towards attaining academic goals.

Srl is a complex theory with multiple constructs supporting the idea of students becoming masters of their own learning. Its constructs include motivation, attitudes, feelings and behaviour oriented towards achieving set goals, self-efficacy, cognition, metacognition, learning strategies and the ability to control these constructs to achieve educational goals.

For the purposes of this study, Motivation and Learning strategies were explored as the main constructs of interest. These constructs were specifically selected because most of the other Srl...
constructs mentioned can be said to be sub-constructs or components of motivation and learning strategies and many of the studies reviewed including Areepattamannil, Freeman and Klinger (2010); Glynn, Brickman, Armstrong and Taasoobshirazi (2011); Watson, Mcsorley, Foxcroft and Watson (2004) attest to this and show motivation and learning strategies to be the main predictors of good academic achievement. The relevance of this theory to the stated problem lies on the literature review findings associating it with coping mechanisms and learning processes that lead to good academic practices discussed intensively in the full paper.

Methodology

The purpose of this study was to provide the current status of the Self-regulated learning constructs; motivation and learning strategies of pre-service teachers majoring in Physical Science education specialisation, at a tertiary institution in South Africa. This purpose was met, through using a mixed methods approach within the pragmatic paradigm to answer two research questions. Two types of data collection instruments (surveys and interviews) were used sequentially to collect quantitative and qualitative data, respectively. This approach enabled the researchers to get an overall idea of students’ experiences as well as more personal experiences to elaborate on the broader idea.

Table 3.1 below illustrates a summary of how quantitative and qualitative data were obtained and analyzed to respond to each of the study’s research questions.

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Research Instruments</th>
<th>Data Analysis</th>
<th>Justification</th>
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</thead>
</table>
| 1. What motivation profiles do pre-service science teachers have?                | Questionnaires (107) and Interviews (18) | Codes, themes, descriptive-stats, graphs and tables | **Surveys**: To provide an overall idea of the current situation  
**Interviews**: To probe for elaborative responses |
| 2. What learning strategies do they use to study Physical Sciences and why?      | Questionnaires (107) and interviews (18) | Codes, themes, descriptive-stats, tables and graphs | **Surveys**: To provide an overall idea of the current situation  
**Interviews**: To elaborate on quantitative findings |

Summary of Findings

The results obtained from this study showed that majority of the participants had positive motivation profiles, however the main motivation factors for majority of participating students to study science were found to be extrinsic. The participants scored the highest for career motivation and were found to be more concerned about what they would gain after finishing the course, instead of focusing on conceptual understanding and/or sharpening their teaching and learning skills.
Majority of the participating students were found to lack awareness and the use of some of the most crucial learning strategies at this day or research and inquiry-based teaching and learning. This is a great cause for concern.

It was also found that having student teachers Self-regulate their learning processes contributed to helping them cope with the rapidly changing scenarios of the present world and hence be able to teach their future learners to do the same. It is therefore very important to continuously explore student’s motivation to choose certain specializations, their learning practices and abilities to regulate their learning processes. Such possibilities will be mapped out in more detail during the presentation. Also exploring how teachers and lecturers can make use of the challenges students are facing to work towards addressing them as they interact with them, motivate and equip them with the necessary strategies that will enable them to succeed as students and as teachers in the future.

It is evident that the teachers of this century need to do more than just learn and teach content, but they need to step up, engage and find more innovative ways to contribute towards ensuring inclusive and equitable quality education and promote research-based opportunities for all.

Conclusion

The aim of this study to explore the pre-service teachers’ motivation and learning strategies used to study science was met. Though academic performance remains a challenge for most physical science students, majority of the students were found to have positive motivation profiles. Majority of the participating students were found to lack metacognitive and resource management strategies, which is a great cause for concern considering the vast developments in technology needing a high level of flexibility and independence. This study has the potential to inform policy making and instruction towards assisting the Universities produce teachers who are motivated, innovative and with flexible teaching practices.

References


ABSTRACT

The present paper with theme: Alternative Techniques of Citrus Conservation in Inharrime aims to reduce the loss of orange in this district. Since much of the orange produced in that district decays a few days after maturation. This rot is accelerated by flying insects (nocturnal butterflies) that suck in the oranges thus causing deterioration. The survey done to the local population shows that they don’t have the solid knowledge to overcome this problem. Thus, this research aims to suggest a low-cost technique for the conservation of orange. The technique proposed to mitigate the loss of orange in Inharrime was the Homemade Production of Orange Jam. After producing the jam was taken to the National Laboratory of Food and Water Hygiene (LNHAA) to test the quality (to evaluate whether it is suitable for human consumption) and was approved by the LNHAA. Subsequently the population was taught to produce for consumption and for sale as a way to contribute to the valorisation and use of the orange in an integral and sustainable way in that district and other points of the country. The population of Inharrime learnt to produce orange jam and now sell in domestic and neighbouring markets.

Keywords: Citrus, conservation, sweet, processing and rotting.

INTRODUCTION

Food production, its conservation and distribution have been since ancient time strategic problems to be solved with the utmost urgency, as it is known that population growth is faster than food availability.

It is the purpose of this paper to present some alternative techniques that will be applied in the home or semi-industrial systems for orange processing and preservation.

According to Ferreira (1994), food decay is caused by several factors that can be classified as: physical, microbiological and chemical agents. The conservation of citrus fruits as a process of preventing deterioration by physical, chemical and microbiological agents or even destruction by insects and rodents can be done by: spraying the orchards, cold storage or by processing fruit into juices, liqueurs, marmalades, candy, etc. So, this research addresses orange processing techniques for jam
production as a way to conserve and take full advantage of this fruit, thus avoiding excessive rotting in that district.

Citrus fruits originate from the tropical and subtropical regions of Asia and are part of the Rutaceae family. These are an important source of vitamin C and also contain certain amounts of vitamins B1, B2 and Vitamin A.

Although in relatively small concentrations, they play vital roles and are indispensable for the regulation of human metabolism.

LITERATURE REVIEW

Geographical location and climate of Inharrime district
The district of Inharrime is situated to the south of the province of Inhambane. The predominant climate in the district is tropical, being dry in the interior, and humid walking to the coast, with two seasons: hot or rainy from October to March and cool or dry from April to September.

In the coastal zone, the annual precipitation in the rainy season is about 1500 mm, with a higher incidence in February and March. In the interior of the district the annual rainfall is about 1000 to 1200 mm, with high temperatures causing water deficiencies (MAE, 2012).

Food Deterioration
According to Gani (2002: 29), the second major cause of food damage is the enzymatic action of food itself and, like microorganisms, food enzymes can also be controlled by heat, cold, drying, some chemicals and radiation.

Food Processing and Conservation
According to Gani (2002: 42), food is processed to prevent or minimize changes, and to develop highly sophisticated food products protected against various chemical, biochemical, physical and microbiological agents that occur after harvest and shorten the shelf life of food. Among several, the main operations that occur in the processing of fruits and vegetables include: washing, selection, peeling, cutting or grinding and bleaching. (AGRO SERVICES, 2006: 4)

To avoid contamination of food, it is necessary to strictly observe the hygiene and safety processing standards of each type of product.

THEORETICAL FRAMEWORK

Nutritional Value and Importance of Orange
Orange is a fruit rich in carbohydrates and vitamin C. Vitamin C has as main functions to assist the body in resistance to infections, formation of bones and teeth, healing of wounds and burns, gives
vitality to the gums, prevents bleeding and preserves the youth, in short, reinforces the body's defences against all aggressions. Its high content of vitamin C, flavonoids and β-carotene, make orange a particularly interesting fruit for cardiovascular health, due to the antioxidant effect of these nutrients. These nutrients with antioxidant properties are also a form of prevention against other degenerative diseases such as cancer (OLIVEIRA, 2006).

Research relevance
After recognizing the economic and nutritional problems that affect a particular population, there is a clear concern to overcome them.

Thus, this theme appears in the attempt to find a solution to mitigate the problem of citrus rot in the district of Inharrime. As orange is a rich fruit in Vitamin C, which, in turn, has as main functions to help the body in resistance to infections, formation of bones and teeth, wound healing and burns, gives vitality to the gums, prevents bleeding and preserves the youth, in short, reinforces the body's defences against aggressions, it was necessary to ensure its permanent to supply in order to alleviate these problems that burden some people of the region.

The population wasted large amounts of orange because of a lack of knowledge and techniques to conserve in order to reduce these losses.

This work will enable them to develop the capacity to identify their food and nutritional problems, possible causes and solutions, and how to act accordingly, in order to contribute to the improvement of the nutritional status of the individual, family and community.

METHODOLOGY

For Denzin and Lincoln (2005) qualitative research is one that seeks to answer questions that emphasize how social experience is created, as well as to investigate situational constraints in order to create a perspective of approach and investigation of a certain problem within society. And quantitative research emphasizes the measurement and analysis of causal relationships between variables i.e. they are examined experimentally or measured in terms of quantity, intensity or frequency.

This research is qualitative-quantitative in nature. Qualitative because it used the interviews and inquiries; and quantitative since it involved the performance of experiments in which it was necessary to perform microbiological and chemical analysis.

This research followed 3 stages:

i. Literature review
Consisted on research of the causes of rapid deterioration of citrus fruits, the techniques used for its conservation as well as the ways of processing orange.
ii. **Field work**
Interviews and inquiries were made to agricultural technicians, teachers, students and the community in general in order to ascertain the real causes of orange rot. Also, the agricultural technicians (extension workers) were sent to the orchards to observe the fruit.

iii. **Experimentation**
The experimental part consisted in processing orange (involving local individuals) to produce jam as an alternative form for the full use of the orange to show and teach the whole community. After performing the first experiment, the product was taken to Laboratory, where it was submitted to two analyzes: microbiological and chemical.

**FINDINGS AND CONCLUSION**

From the study made in Inharrime, it is known that there were evident actions of conservation of orange in that region of the country.

The population did not have sufficient knowledge about the conservation of the orange; so, had to learn to make effective this practice in that district. This rotting was due to the lack of market for the sale of orange, because in the harvest period the local market has this fruit in excess. Therefore, as a strategy to mitigate the rotting of orange, was implemented the production of orange jam which is easy food to process and preserve for a long time. The population was taught the techniques of homemade processing of orange to produce the jam for later consumption and sale in the post-harvest period. Orange jam was approved as energetic food, can be administered as a supplement for athletes and to improve nutrition deficiencies. The production of the jam of the orange allows taking advantage of the orange of integral form; for the reason that producing the jam, the orange is harnessed from the fiber to the juice. Since orange is a fruit rich in nutrients that have been wasted when it is consumed in different ways.

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DEVELOPING PEDAGOGICAL CONTENT KNOWLEDGE TO PROMOTE SCIENTIFIC LITERACY USING CLIMATE CHANGE AS A THEME TO TEACH PHYSICAL SCIENCE CONCEPTS TO GRADE 10 LEARNERS: A Self-Study
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Abstract
Anthropogenic climate change is supported by solid scientific consensus and its consequences are becoming more definite globally (Ward, 2016). In South Africa persistent flooding, droughts and famine have devastated many parts of the country and caused socio-economic and ecological losses. This has highlighted the beginning of an awakening of the citizenry to the multifaceted impacts of warming global climate systems. Science education has been identified as a tool that can transform communities therefore it goes without say that scientific literacy is critical in coming up with strategies to address anthropogenic climate change. On the contrary there is a drawback in the South African Physical Sciences school curriculum to focus on Socio-Scientific Issues (SSI) (Nakedi et al., 2012). The topic of climate change provides a context to explore the interconnections of science, society, technology and ecology (STSE). The theme of climate change has the potential to conscientize learners and alters their everyday interactions in a world shaped by anthropogenic climate change (Sullivan et al., 2014). The levels of climate literacy that the masses possess are currently inadequate to address the magnitude of climate change (Herman et al., 2017). Teachers therefore, need Pedagogical Content Knowledge (PCK) to teach climate literacy in ways that are accessible to both learners’ cognitive domains and their lifestyles. This paper reports on a self-study to investigate my efforts of using climate change as a SSI to teach the topic of Chemical Systems to a grade 10 Physical Science classroom under the supervision of the second author.

The constructs that underpin the study are situated cognition, PCK, scientific literacy, self-study and SSI.s Situated cognition is one of the social standpoints with crucial contributions to teaching and learning processes since it purports that knowledge is embodied in socio-cultural and physical practices (Lave & Wenger, 1991). Therefore, learning involves concurrent increase of knowledge and competences in situations rather than a teacher to learner download of information about the social world (Brown et al., 1989). The implication for practice is that connections of actual social situations with classroom science are crucial for intelligible science learning to occur. Sensible science education is envisioned to embrace both visions of scientific literacy (Roberts et al, 2011). Vision I focuses on traditional knowledge of scientific constructs and nature of science. Vision II focuses on the relations of science and socio-economic factors and skills to deal with these links to integrate STSE in sustainable means. This knowledge will capacitate learners to engage in SSI.s at an individual or a
collective dais to effect positive ecological experiences as responsible citizens. To achieve this teachers require an elaborate PCK which constitute professional knowledge and skills to teach climate change.

The conceptual and analytical framework I adopted draws from the SSI model proposed by Presley et al., 2013 that embodies 3 components i.e.; design elements, leaner experiences, and teacher attributes and the Learning Teaching through participation (LTtP) proposed by Nakedi (2014) which is grounded in the view that reflection serves as a dynamic force that facilitates coherent interactions through continuous reconstructions of classroom practices that embodies the teachers’ PCK. The Presley et al. design elements encompass the planning that goes into teacher thinking about the way they are going to structure the lesson involve the build up of concepts around the issue in question, what resources gravitate towards authentic practices and experiences are going to be used to bring constructive learning to learners by using cognitive crutches to navigate learners’ zones of proximal development. These are experiences that learners need to engage in as the co-construct scientific understandings on the SSI. These constitute higher order cognitive skills of STSE reasoning and NOS that gravitate towards science literacy polarized along constructs and procedural methodologies in science and how scientific knowledge is generated. Teacher attributes underpin the design elements from which learners’ experiences are drawn from. This encompass general content knowledge the intricacies embedded in SSI and general pedagogical understandings that relate to SSI particularly the anomalies and uncertainties in scientific inquiries. The conduct of learners in the classrooms that involve various experiential activities to enhance learning experiences as they construct new understandings in classroom settings. The LTtP model serves as a conceptual tool to frame the teachers’ PCK in the context of a self-study by articulating the interactions and resultant trajectories of the teachers’ personalized knowledge reconstructions through the knowledge domains. It positions the construct of PCK within a continuous integration at different orientations which will be captured by the research tools.

In this paper, I analyzed the structure of my content knowledge of climate change by comparing the pre-and post-concept maps. A concept map rubric was used to score the concept maps a measure of their structure of content knowledge that underpin what teachers teach in the classroom (Tullberg et al., 2007). The rubric assesses five components of content knowledge that constitute the concepts, groupings, hierarchy, branches, and propositions. In terms of the concepts the pre-concept map had a relatively lower magnitude of concepts that the rubric identifies to relate to the theme of climate change. The post-concept map had more concepts that pertain to climate science. The number of concepts the pre-concept map constructs had limited diffusion across the topic of climate change. The pre-concept map had limited diffusion of concepts across geocentric and atmospheric processes. The post-concept map had a wider disposition of concepts along all the critical areas of climate science which are atmospheric, ecocentric, anthropogenic, geocentric, and NOS. The shift in content knowledge by the teacher in the self-study gravitated towards more and varied abstractions of climate change illustrated in figure A.
The teachers’ hierarchical structures of concepts changed from less to more concepts structured from general to more precise in the transition from pre- to post-concept maps. This result is analogous to the branching of constructs which deal with the connections in any dimension without any classification. The pre-concept maps were concealed to two statement lines while post-concept maps were substantial with more two and three statement lines. The connecting words from everyday life and scientific discourse constitute the propositions in the pre- and post-concept maps. In the post-concept map the teacher was able to articulate more simple and scientific words relative to the pre-concept map. The registers in the pre-concept map were implicit and resulted in thin descriptions from one conceptual node to another. While the rich vocabulary in the post-concept map was more explicit and consequential in creating word combinations that integrate the common sense and scientific understandings.

An inferential paired t-test was used to evaluate the meaning of differences between pre- and post-concept maps with \( d = 7.8; \) SEM = 1.6; \( n = 5; \) d.f= 4; and \( t0 = 4.87; \) and \( p = 8/1000 \approx 0.008 \) meaning that the difference between the maps where not by statistical chance As a practitioner capacitated with gains in structure of content knowledge this component of my PCK aids to consolidate my content knowledge and reconcile what I had learnt to advance good constructive practices by developing a solid knowledge integration of climate science using concept mapping. The structure of how I orient my constructs is critical to identify the core concepts that underpin the big ideas in the topic. Concept maps in this regard improve my curriculum saliency by providing cognitive tools to organize and sequence the concepts in ways that interconnect with big ideas in cogent ways that integrate constructs to make them more meaningful learning components. Therefore, concept maps were incorporated into lesson design to generate the big ideas and present them in ways that are intelligible for learners. The core concepts of the topic are made explicit in the concept maps and this helped to develop my knowledge base of pedagogy.

References:


TEACHING ELECTROMAGNETISM FOR THE FIRST TIME: A Case Study of Pre-service Science Teachers' Enactment of PCK

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Abstract
This paper reports on a study following three pre-service teachers into schools where their teaching of electromagnetism during their formal teaching practice module was observed. An interpretive, qualitative case study was conducted searching for evidence that they could translate the knowledge attained during a preceding methodology module, when teaching the topic for the first time. Findings suggested that pre-service teachers were able to enact learned TSPCK and to make better decisions about sequencing of concepts and instructional strategies after the first time of teaching the topic.

Introduction
An opinion raised by experts in the field of PCK is “…one major, if not the main theoretical premise behind studying PCK, is that teachers with higher levels of PCK are better able to help students learn” (Kirschner, Taylor, Rollnick, Borowski, & Mavhunga, 2015, p. 234). It is therefore reasonable that teacher education concentrates on ways to capture and develop the PCK of student teachers. Naturally, this development of PCK of student teachers should start during the theoretical and practical aspects of their training. As such, this paper focuses on the practical experience of student teachers when teaching electromagnetism for the first time. It emerges from a broader study that explored the development of pre-service science teachers’ PCK as a result of explicit instruction in the components of TSPCK (Mavhunga, 2012) about teaching electromagnetism.

Literature review
Literature on different aspects of PCK in science teacher education reveals that content knowledge (CK) about a specific topic and its PCK are often studied in tandem (Davidowitz & Potgieter, 2016). This is in agreement with Shulman’s (2015) argument that strong CK is a necessary (though not sufficient) prerequisite for successful teaching. In this study electromagnetism was selected as a topic to explore the TSPCK of student teachers, as it is generally regarded as a difficult topic to teach and to understand, mainly because of its abstract nature (Dori & Belcher, 2005). In the South African school curriculum, electromagnetism is introduced in Gr 11 with two main topics; the magnetic field around a current-carrying conductor and Faraday’s law. Magnetic flux is introduced as a sub-topic under Faraday’s law. (Department of Basic Education, 2011).
Aim of the study

The study aimed to search for evidence of manifestations and interaction of the components of TSPCK about electromagnetism when taught by the pre-service teachers. We also explored these students’ pedagogical reasoning about their teaching. The study is guided by the following question: How do pre-service teachers enact TSPCK about electromagnetism when teaching the topic for the first time?

Conceptual Framework

![Conceptual Framework](image)

*Figure 11: Conceptual framework for the study.*

We adapted the framework of Smith and Banilower (2015) to include reasoning that emerged from Mahvunga’s TSPCK framework (2014) and from the refined consensus model (RCM) (Carlson & Daehler, in press), to develop a conceptual framework that supports this study (Figure 1). The collective PCK can be considered as canonical, belonging to the profession. For the purpose of this study, it is described by the five components of TSPCK as related to the teaching of electromagnetism and was taught during the intervention.

Through instruction, as during pre-service teacher education, the collective PCK shapes the personal PCK of the student teacher. In the RCM the teacher’s personal PCK is considered as a “reservoir of knowledge and skills that the teacher can draw upon during the practice of teaching” (Carlson & Daehler, in press), which resonates with the definition of personal PCK by Gess-Newsome (2015, p. 36):

“Personal PCK is the knowledge of, reasoning behind, and planning for teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes (Reflection on Action, Explicit).”
During teaching practice, the student teacher also gets the opportunity to employ the newly developed or enhanced PCK in actual teaching situations (enacted PCK), which in turn shapes the personal PCK of the student teacher. The arrow that indicates feedback from the enacted PCK to the personal PCK lies beyond the scope of the study.

**Methodology**

In the broader study, an intervention took place that formed part of a Physical Sciences methodology course in the first term of the student teachers’ final year. During the intervention, the five components of TSPCK were explicitly addressed using appropriate sub-topics in magnetism and electromagnetism. The way each of the five components supports the transformation of content knowledge for teaching, was communicated. During the second and third terms of the year, the student teachers were exposed to formal teaching experience. Some of the students, who underwent the intervention, were afforded the opportunity to teach electromagnetism to Gr 11 learners during the third term teaching practice. Of this group, three students, diverse in terms of gender, race, first language and language of instruction were selected to form the sample for this study.

At least sixty minutes of teaching electromagnetism by each of these students were observed and video-recorded. After completing a full cycle of teaching electromagnetism, the students were interviewed. One part of the interview was semi-structured and prompted the students to reflect on general aspects of their teaching. The second part was a video stimulated recall interview during which the students were asked to view sections of their lessons and comment on their actions and decisions.

During analysis of the lessons and interviews, we searched for evidence of competent manifestations and interaction of the components of TSPCK as taught during the intervention. The components of TSPCK served as predetermined codes during coding of the lessons. Interaction of TSPCK components was indicated when two or more components emerged during a single event in the lesson. Furthermore, a rubric for assessing enacted TSPCK was designed to establish the level, restricted, adequate or rich, at which the TSPCK was enacted. The interviews enabled us to elicit the student teachers’ pedagogical reasoning about their teaching, which could not be accessed through lesson observations only (Chan, Rollnick, & Gess-Newsome, in press) and gave a rich picture of a students’ enacted TSPCK.

**Findings and Conclusions.**

The extent to which the students enacted TSPCK differed for the three students and over different electromagnetism concepts. The components enacted at the highest level were Curricular Saliencey and Representations, where What is difficult to teach and Learner prior knowledge lacked richness in the lessons of two of the participants. These students missed opportunities to correct learners’ unscientific thinking and unintentionally reinforced misconceptions. During the intervention, it was
suggested that magnetic flux should be taught explicitly before Faraday's law. Surprisingly, the students did not follow this sequence but attempted to teach Faraday's law first. Reasons for this decision were not given, but they commented in their interviews, after teaching, that this sequence was very inefficient and that magnetic flux should be taught explicitly before Faraday's law. In this case, experience convinced them of the significance of the discussion that took place during the intervention. Evidence from the lessons and interviews revealed that the student teachers found magnetic flux a difficult topic to teach. The findings suggest that when students are not comfortable with the content, they do not integrate the components of TSPCK effectively and their instructional strategies seem to collapse.

References


DEVELOPING SCIENCE LEARNERS’ CLIMATE CHANGE LITERACY: A Science Teacher’s Self-Study
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Abstract
Climate change is a global issue that we are all currently facing with its associated extreme weather conditions which have an impact on all areas of our lives. Education is an engine of any societal change and therefore we need to develop climate change literacy amongst our learners if we are to have any hope of averting certain disaster. I am currently undertaking a self-study to develop my pedagogical content knowledge (PCK) for teaching this topic with the aim of raising my learners into climate change literate agents of change. The nature of self-study as a personal journey requires use of multiple qualitative research tools as well as the exposure of processes to public scrutiny to ensure credibility and trustworthiness in findings. This paper reports on the content representation (CoRe), concept map and teaching programme I have developed using the information from a diagnostic assessment of my learners as well as the feedback received from a group forum.

Introduction
We live in the continent which is most vulnerable to the change in climate: Africa. The situation is intensified by existing developmental challenges which include poverty, poor governance and the lack of infrastructure and technology. If education is effectively organised and administered, it will allow our learners to become climate change literate and provide them with the necessary skills required to address the issues at hand. Emphasis should be placed on the skills, values and attitudes required to identify and help resolve environmental challenges through the promotion of critical thinking, problem solving and effective decision-making skills rather than merely knowledge of the topic (Torkar, 2014).

Conceptual framework and literature review
Socio-scientific issues (SSI) are controversial, socially relevant, real-world problems that are informed by science and often include an ethical component which engage learners in their learning. This type of learning is open to exploration, inquiry and integration of multiple disciplines. Research on using socio-scientific issues to teach science has not only shown improved content knowledge among learners but also increased learner interest and motivation. An improvement of the development of higher order thinking skills and increased understanding of the nature of science in learners was also noted (Klosterman and Sadler, 2010). The teaching of SSI focuses on empowering learners to consider
how science-based issues affect not only their own lives but as well as the physical and social world around them. The approach therefore requires learners to develop a position on controversial real-world issues, discover evidence that supports or refutes their position and communicate with their peers. This develops skills that will serve them both in their future academic studies and in the workforce (Latourelle, 2016). To nurture our learners into future citizens and leaders who care, serve the community and provide leadership for new generations it is necessary for us as educators to incorporate SSI into our teaching.

A variety of frameworks for teaching SSI have been developed by researchers but most of these studies have not focussed on PCK for SSI (Tosunoglu & Lederman, 2016). The idea of PCK was first proposed by Lee Shulman in the 80s and researchers have been trying to get to the core of what it really is ever since (Bishop & Denley, 2007). PCK can be described as a unique type of knowledge that is gained through experience and over time which results in a more meaningful learning experience for learners. It is how to teach the curriculum in a way that improves the understanding of the learners and it is an expertise that differs among teachers and among subjects (Loughran et al., 2012). I have therefore chosen PCK for SSI as my conceptual framework and have chosen the framework developed by Presley et al., (2013) for socio-scientific issues-based education to analyse my teaching programme.

**Methodology**

I have chosen self-study as my research methodology as it can be a meaningful way to better understand the complex nature of teaching in ways that can be informative not only to my practice but provides a way to articulate and communicate the findings which can be beneficial to others. Self-study as a research method employs a variety of qualitative data collection methods. My study therefore makes use of a variety of research tools to ensure a rich and wide range of data. I have subjected a variety of my data collection methods to scrutinization by critical peers which include my supervisor and colleagues whose research is also centered around the climate change literacy amongst learners. I will analyse my plans for teaching climate change according to the three core aspects of the SSI-based framework namely design elements, learner experiences and teacher attributes.

**Findings**

The first core aspect identified by the framework is the design elements which asserts that the instruction should be designed around a compelling issue such as climate change which I have chosen. The instruction should be scaffolded to facilitate higher order practices and I have therefore chosen the chosen the inquiry-based learning strategy of the 5E instructional model. This instructional model outlines a sequence of five sequential steps: Engage, Explore, Explain, Elaborate, and Evaluate. An inquiry-based educational tool such as this promotes active participation of learners. The stage will be set for inquiry by introducing the issue at the beginning of the instruction
as recommended by the framework. The curiosity of learners will be peaked with strategies that include See-Think-Wonder, Think-Pair-Share and the use of visual thinking maps. The exploration phase will then make use of a rotation station which offers an innovative and engaging approach. This phase provides the learners with the opportunity to engage with the concepts and explore on their own before the explanation phase. The explanation phase will provide an opportunity for all the knowledge obtained during the exploration phase to be brought together with my explanation of key concepts using demonstrations as well as collaborative discussions and experiments. The concepts will be dealt with in a more in-depth manner through the elaboration phase. Lastly, the learners will be evaluated through both formal assessments such as a quiz as well as informal assessment techniques such as I used to think but now I think. All these experiences will provide a culminating experience for the learners which is the final requirement for the design element of the framework.

The experiences that learners need to engage in such as higher-order practices is the second criteria identified by the framework. This has been achieved through activities such as a stakeholder roleplay that the learners will partake in during the Elaboration phase of the teaching programme. This roleplay will result in more in-depth knowledge of the concepts and theories being discussed, provide an opportunity to explore and gain understanding of alternative viewpoints as well as develop communication, critical thinking and argumentation skills.

The final core aspect of the framework is that the teacher should have certain characteristics in order to successfully facilitate the instruction of SSI in the classroom. The first characteristic identified by the framework is that the teacher should be familiar with the issue by being both knowledgeable about the science content behind the issue as well as the social considerations of the issue. Both of which are evident in my detailed pre-Core and concept. The second characteristic identified is the willingness of the teacher to learn and be a facilitator rather than the source of all knowledge. I have shown my willingness to learn by undertaking a self-study and subjecting my teaching practice as well as my programme to the scrutiny of critical peers and have positioned myself as a facilitator by using the 5E instructional method.

**Conclusion**

To conclude, it is key that our learners become conscious of their attitudes and practices many of which are harming our planet. I believe that the teaching programme which I have developed will be successful in achieving that goal as it meets the requirements necessary for a socio-scientific issues-based instruction.

**References**


THIRD YEAR UNIVERSITY STUDENTS’ ACCOUNTS FOR CHOOSING CHEMISTRY

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Aim

This study is part of a broader doctoral research project concerned with addressing the factors that affect the retention of chemistry students at University of Cape Town (UCT). Specifically, the study attempts to examine the collective influence of career aspiration, self-efficacy and conceptual understanding on the retention of third year students from the Extended Degree Programme (EDP) and mainstream; using a constructivist approach and a qualitative case study design. However, for this paper the spotlight is focused on an aspect of the data derived from semi-structured interviews pertaining to why students choose chemistry and is guided by the research question:

What criteria did third year chemistry students from EDP and mainstream use in deciding their study programme?

Introduction and Literature Review

Several studies have reported the loss of highly talented and academically able students in science faculties to other non-science based faculties; or to outright discontinuation from college (Villafañe & Lewis, 2016). Career aspiration, cognitive factors such as prior conceptual knowledge in science, prior maths skills and affective factors such as attitude, self-efficacy have been reported by many researchers to affect students’ performance, motivation, persistence, and their decision to stay in the programme (Lubben et al. 2010; Ogunde et al. 2017). Woolnough (1994) explained that students’ prior learning experiences, motivation by educators and academic abilities plays important roles during the initial stages of choosing their study programmes. It is pertinent to highlight that various studies have been conducted on Access Programmes e.g. the Extended Degree Programme at the University of Cape Town, but most of these studies focused on first- and second-year students. This study takes a different approach by focusing on third year chemistry students (drawn from EDP and mainstream), who are enrolled in a third-year chemistry course to better understand the role that career aspiration, self-efficacy and conceptual understanding has played in their retention. Thus, unlike previous studies, this study looks at these students when they are in their final year to identify from their stories the factors that have helped them to persist.

Theoretical Framework
The findings emerging from the study is compared with the work by Gardner, (1985) and Woolnough (1994) on students’ strategies for choosing tertiary study programmes which have been suggested to be based on these criteria: interest in the subject, achievement in the subject at school level, extra-curricular experience in the subject area, influence of role models, pressure and stimulus from family, interest in the study programme outline.

**Methodology and Findings**

The convenience sample of 18 interview participants out of a class of 32 consisted of students of diverse ethnicity who have successfully entered their final year. Interview transcripts were subjected to qualitative inductive thematic analysis.

This an ongoing project however, I present a discussion on the criteria used by EDP and mainstream students respectively in deciding their study programme, comparing it with the work by Gardner, (1985) and Woolnough (1994). Five of the criteria revealed in the data gathered in this study matched those in the literature, the exception being interest in the study programme outline as seen in the chart below:

![Figure 12: Chart showing the criteria used by EDP and Mainstream students in deciding study programme](image)

For the 10 EDP students that were interviewed in this study, the most frequent criterion used in deciding their tertiary study programme was their achievement/grades in the subject in high school as seen in the next quote: “I was good at chemistry in high school, I choose chemistry”. The criterion that ranked second was an interest in the subject: “Ok, so in high school, I really liked chemistry”. This was followed by influence of role models, their extra-curricular experience and pressure from family respectively. Lastly, the influence of pressure from family was mentioned by one EDP student who explained that it was her parents who convinced her to apply for medicine even though she was not interested in being a medical doctor as typified: “And not that medicine was my first choice, I did it because my family convinced me to do it”.

In comparison to the EDP students, it was observed that out of the 8 mainstream students that were interviewed in this study, role models had the greatest influence on their decision in choosing a tertiary study programme as evidenced: “It was actually one of my teacher who was very good, that spotted my interest and encouraged me”. The next criterion that ranked second was interest in the
subject as seen in a student comment: “I signed up for BSc. Chemistry has always been one of my majors”. The influence of the criterion of “pressure from family” was not recorded in the conversation with any of the mainstream students. Additionally, UCT requiring two majors was an emerging reason both EDP and mainstream students gave for choosing chemistry which was recorded as a second choice for most of them as evidenced: “And when I came here, they said you must have two majors, so I decided to take chemistry”, "So, I choose chemistry as my second option on that day", “So, this was my 2nd choice"

In summary achievement in the subject at school level, interest in the subject and influence of role models were the foremost criteria that influenced undergraduate students’ choice of study programme. The former was the most prominent criterion that EDP students used whereas the latter was the most prominent for mainstream students. This will be probed further with students’ career aspiration, self-efficacy and conceptual understanding. It is recommended to replicate the study in a different socio-cultural context to see if a similar finding is obtained.

REFERENCES


Understanding Your Learners: Developing and Implementing Learning Style-Based Instructions in a Physical Science Classroom

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Abstract

Physical science is a critical subject for the entrance into the scientific and technological world. Yet, very few learners study and succeed in the subject. Most learners have a misconception that the subject is too difficult to study and comprehend. However, research has also shown that all learners have strengths and abilities, but each learner may have a preferred way of using these strengths and abilities for learning. This preferred way of learning is referred to as learning style. Understanding that each learner has unique strengths and weaknesses related to the ways in which they approach learning is an important component of effective instruction. Thus, this study therefore seeks to develop and implement a learning style-based instruction in a science classroom that combines four dimensions of Felder-Silverman Index of Learning Style profiles of learner in the design and implementation of learning style-based instructions in the physical science classrooms.

This study was therefore, conducted by using mixed methods design. The sampled teachers received training on the development and implementation of learning style-based instructions. Data was collected by means of classroom observation schedules, structured questionnaire that was completed by a sample of 131 grade 11 learners from four high schools. This was followed by individual interviews with 10 learners and five teachers. Data was analysed descriptively to identify the learners learning style profiles in the science classroom. The larger qualitative part was analysed using thematic content analysis. The study found that the predominant learning style amongst the learners in the sampled schools were active, sensing, visual, and sequential learning styles. The study further determined that gender significantly influence learners’ learning styles.

Findings from the study revealed that the learning style-based instruction improved learner retention and interest in the subject. It is therefore recommended that, learning style-based instructions should be implemented in order to retain the learned material for a longer time.

Keywords: learning style-based instructions, learning styles, learners, physical sciences

Introduction
Physical science is a critical subject for entry into the scientific and technological world. Yet, very few learners study and succeed in the subject. Most learners have a misconception that the subject is too difficult to study and comprehend. A study conducted by Trend in International Mathematics and Science (TIMSS) in 2011 found that South African performance was poor (Reddy et al, 2013). This poor performance of learners in physical sciences could be due to learners learning style differences, instructional strategies that are not in congruence with the learners learning styles and lack of interest in the subject.

Nevertheless, in the learning situation, however, every learner has his/her own natural ways of acquiring and processing information. These unique ways are described by Singh, Govil and Rani (2015) as their learning styles. In literature numerous learning styles and learning style models exist due to the fact that learning is achieved at different levels. In the same way, instructional strategies also vary. According to Felder (1988), some teachers teach by demonstrating, others by lecturing; while others emphasise on principles and applications. Hence, how much a learner learns in a classroom is often due to the learners’ inherent ability and prior preparation as well as the match between the learners’ learning styles and the teacher’s instructional strategies. Sometimes mismatches occur resulting in some learners getting bored or discouraged and may perform poorly in examinations.

Against this background, the study designed and implemented learning style-based instructions in grade 11 science classrooms.

**The development of learning style-based instructions**

Developing learning style-based instructional strategies involves diagnosing individual learning styles preferences; determining class strengths and weaknesses, examining the subject content for the area that may create difficulty for learners and analysing learners prior achievements scores, assessing current instructional strategies to determine whether they are adequate or require more modification in the learning environment and developing personalised learning experiences (Keefe, 1991). Instructional strategies are used in different ways to implement different teaching strategies which are matched with different learning styles. For example, a demonstration-based teaching strategy can be used in different ways. It can be used to assign a hands-on activity to learners in such a way that learners can solve the assigned problem in a collective manner. This fits well with sensing learning style. The demonstration-based teaching method can also be used to give a sequential series of theoretical presentations to learners who can interact with the teacher.

Hence, the objective of this study has a central focus on the creation of teaching methods and environments that utilises the teaching material and strategies in congruence to the learner’s learning style. The researchers used Felder & Silverman (1988) model for defining learning styles.
It was found from the literature reviewed that the Felder-Silverman’s learners are different in their characteristics with each other. Therefore, the researchers designed instructional programmes involving different instructional strategies based on different learners’ learning styles.

The following steps were followed when developing learning style-based instructional strategies.

- Analysis of subject content
- Lesson planning for each sub-topic
- Pilot testing the lesson plans
- Expert opinion on lesson plans
- Final form of Teaching Programme for implementation.
- Content analysis in the view of instructional strategies

The topics selected for teaching were further analysed keeping instructional strategies in mind. The purpose of content analysis was to validate if instructional strategy would be more appropriate for each sub-topic. For example, the following topics were analysed for the first topic on ‘electrostatics.’

1. Coulomb’s law
2. Electric field

The topics were found to be demonstrative, descriptive and deductive. This implies that, different instructional strategies should be utilised to teach the learners with different learning styles in the science classroom. For the visual/verbal learners, demonstration and discussion teaching methods were most appropriate for teaching these topics, whereas for the active/reflective learners, brainstorming and case study were most appropriate for teaching.

![Figure 1.1: instructional strategies for input, processing, perception and understanding learners](image)
References


TEACHING OF LIFE SCIENCES: At the Association of Muslim Schools
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Abstract
This paper reports on data collected from Life Science teachers, the director, chair and principals of the Association of Muslim Schools KZN region. The findings of preliminary data emphasized the need to explore the teaching of Life Sciences at the Association of Muslim Schools. The main questions that guided the study are as follows,

• Is the vision of the Association of Muslim Schools (“To provide a range of quality services which will enable our schools to deliver an Islamically based-education of the highest standard and quality” maintained and carried out by all schools in the region in its teaching and learning?
• Are all Life Science teachers at the school Muslim?
• Do the pedagogical approaches used by Life Science teachers incorporate the values of Islam?

Data will be collected by means of a questionnaire, classroom observations, and artefact analysis. An inductive approach will be used for the analysis of data. The conceptual framework that guides the study is the philosophy of Islam and its approaches for the teaching of the mandated Life Sciences curriculum.

Introduction

The Muslim community extends not to South Africa, Australia or North America, but across the entire world. The Islamization of Knowledge process is considered as one of the most important and intellectual movements in the 20th century, while the concept of Islamization of Science is approximately thirty years old (Madani, 2016). The South African culture is diverse, with schools not only wishing to instil the CAPS curriculum on its learner but also to instil values that go beyond this narrow curriculum. The Association of Muslim Schools (AMS) comprises of schools that serves well over 20 000 learners while its staff incorporate all strata and shades of people from the community. The vision of the Association of Muslim Schools is to provide a range of quality services which will enable schools to deliver an Islamically based-education of the highest standard and quality.

According to Yaacob and Embong (2008), one of the crucial issues that is facing the contemporary Muslims stems from the problem of educational dualism. Khan (2015), divides knowledge into two streams namely, the knowledge of religion and the second is the knowledge required by community. The short coming of the above streams is that when there is a strong focus on religious education, the end result is religious specialists that are unable to actively participate in society due to a lack of
critical and creative thinking (Yaacob and Embong, 2008); while national education produces professional that are deficient in religious knowledge.

The problem statement of the study is that within the Association of Muslim Schools (AMS) the staff compliment consists of both Muslim and non-Muslim members. Consequently, a non-Muslim teacher would not be able to teach Life Sciences from an Islamic perspective, simultaneously those Muslim teachers although they are well versed in their religious background, they may lack Islamic pedagogical approaches for the teaching of Life Sciences.

**Literature Review**

The meaning of the word “Islam” is submission to the will of God (AL-Abdulkareem, 2004). Expanding on the concept of the dual education system in Islam, is the western paradigm and the Islamic theory of knowledge. The western paradigm is based on materialism and provides a specific theory of knowledge and limited world view (Arif, 1987). Thus, theories of teaching, learning, curriculum and evaluation would be a part of the general education theory (Farhan, 1989). While the Islamic epistemology stems from the premise that original all knowledge is Allah’s knowledge (Arif, 1987). Consequently, education from an Islamic perspective is a form of worship and therefore a prerequisite obligation and responsibility for the individual, and the society (Farhan, 1989). Islamic schooling falls into three overarching categories, namely the supplementary weekend and evening religious instructions; the madrassa schools that place emphasis on the religious sciences; and thirdly the full-time day schools that follow the mandated CAPS curriculum while integrating a religious world view. The Association of Muslim Schools can be categorised as the third type of school in South Africa. Consequently, seeking to nurture a sense of faith consciousness through basic beliefs, practices, and an Islamic worldview that is embedded across the ethos, teaching, and curriculum of the school (Memon, 2011).

Teaching is a profession that involves special forms of knowledge and skill (Bullough, 2001). A science teacher possesses the appropriate educational and experiential background including both practical teaching experience and knowledge of the history and trends in science teaching and learning (Rossier, 2003). Empirical studies have indicated that although the number of faith-based schools have increased across the globe, there is no formal accredited teacher education programme for Islamic school teachers in countries such as North America, Australia, Europe (Memon, 2011) and South Africa. Teachers in Islamic schools often have relied on professional development conferences workshops that could assist them.

The mandated Life Sciences CAPS curriculum incorporates sections on evolution, cloning, abortion and genetic engineering. For non-muslim of Life Sciences teachers at the Association of Muslim Schools and across the world such sections can pose potential problems for them (Roth & Alexander, 1997; Brickhouse, Dagher, & Shipman, 2000; Cobern & Loving, 2002; Shipman, Brickhouse, Dagher, & Letts, 2002; Colburn & Henriques, 2006; Stolberg, 2007, 2008; Hokayem & BouJaoude, 2008).
Primarily because it goes against the beliefs of Islam (Mansour, 2010). According to Mansour (2010), science teaching from an Islamic perspective must be active in verifying facts and discovering that which has not yet been discovered and explain it through religion. However, the personal religious experience of an individual, (particularly teachers of the non-muslin faith) is an influential factor in gaining and/or interpreting experiences, consequently influencing the pedagogical beliefs and classroom practices of teachers (Brickhouse, Dagher and Letts, 2002 and Roth and Alexander, 1997). Existing research studies have revealed that teachers’ epistemological views of science influences how science is conducted and portrayed in a teacher’s classroom (Lederman, 1992). Lederman (1992), further state that the teachers’ scientific epistemological views are often consistent with their instructional beliefs and practice. Teachers form and develop classroom practice theories based on personal experiences gained in their classroom practices over the years (Lotter et al., 2007).

A common definition of pedagogy is the “study of teaching methods, including the aims of education and the ways in which such goals may be achieved” (Pedagogy, 2018). Islamic pedagogy is a means through which religious knowledge is transmitted in order to inculcate Islamic values and beliefs (Diallo, 2012). When it comes to teaching from an Islamic perspective Niyozov and Memon, (2011) state that the principles of Islam will remain at the center and serve as the overarching epistemological and ethical framework. Hence Memon (2011) advocates that an Islamic pedagogy must articulate principles of education that allow for a fluidity of practice and multiplicity of interpretation and adaption. One of the principles of Islam is focus on what is correct rather than that which is wrong, Sabrin (2010) further states that on correcting mistakes in general, there are several cases where the prophet Muhammad stressed to people the reason why what they were doing is wrong, rather than hastening to condemn them; and in many instances offering them more appropriate alternatives (Al-Nisaa’i, 1119 in USC).

**Theoretical Framework**

The theoretical framework that informs this study is based on the philosophy of Islam and that this philosophy has its own approach to the teaching of Science. Conceptualising the current challenge that exists at AMS is shown in diagram 1 below. It is evident that in order to maintain the over-aring vision of the association the gap that exists needs to be filled. AMS is currently home to teachers from all religious spheres across subjects. Consequently, the beliefs of teachers influence their classroom practices (Dhurumraj, 2017). Material that presents the mandated CAPS curriculum and is integrated and unified with the Islamic perspective is needed for teachers in these schools. Further to this these teachers need to be equipped with Islamic pedagogical approaches for the teaching of Life Sciences at the Association of Muslim Schools thus taking the association a step further towards closing the gap between teaching and upholding its vision of delivering a high standard Islamically based education.
Diagram 1: The Current State at the Association of Muslim Schools

Methodology

A qualitative research approach which makes use of an ethnographic design is used for this research. Ethnography is defined as the art and science used to describe a group or culture (Sangasubana, 2011). This design is preferred because the study aims at developing cultural awareness amongst Life Science teachers at the Association of Muslim Schools.

Convenient sampling is used for the selection of schools and its participants (life science teachers). Data Collection techniques include the use of questionnaires, document an artefact analysis, participant observations, and interviews.

References


THERMAL CAMERAS AS A SEMIOTIC RESOURCE FOR TEACHING SCIENCE IN SOUTH AFRICAN TOWNSHIP SCHOOLS

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Abstract

This study investigates how thermal cameras can be used in meaning-making around thermal phenomena. Predict-observe-explain (POE) tasks were conducted with Grade 7 and 8 learners in two township schools. Results showed that learners coordinated multiple semiotic resources including dynamic thermal images, spoken language and touch in reasoning about heat and temperature. Although results support the literature in that inquiry-based approaches are challenging to implement in this context, the Grade 8 learners indicated that true dialogue was possible to achieve by demonstrating different lines of collaborative inquiry.

Introduction and Objective

The South African Curriculum and Assessment Policy Statement (CAPS) promotes inquiry-based instruction, guided by students’ questions and curiosity (Department of Basic Education, 2011). However, research indicates that it is challenging to adopt inquiry-based approaches in disadvantaged South African schools (Clark & Linder, 2006; Ramnarain, 2014). Our work in a Swedish context (Authors, 2014, 2015, 2016) has used infrared (IR) cameras (Fig. 1) to develop inquiry activities for thermal science, a core component of international science curricula. These activities are found to catalyse “what if” explorations driven by meaning-making power offered through simple laboratory setups.

From a multimodal perspective (Jewitt et al., 2001), infrared imaging affords an opportunity to engage with thermal phenomena through vision, as a complement to the sense of touch. A South African and Sweden collaboration is exploring how thermal cameras can stimulate inquiry-based activities in Grade 7-8 South African township classrooms. This study investigates how thermal cameras can be used as a semiotic resource for meaning-making of thermal phenomena.

Literature Review

Heat conduction is the transfer of energy by molecular activity from an object of higher temperature to an object of lower temperature. The fact that metals feel cold to the touch, while wood at the same temperature feels warmer, induces many learners to believe that metal has a lower temperature (Erickson, 1985). Apart from heat conductivity differences as the classroom explanation,
understanding heat conduction is also dependent on cultural and personal contexts (Rosebery et al., 2010). Experiences of heat conduction from insulating a corrugated iron home in a South African township context is different to experiences of holding snowballs in Sweden. Also, terms used to communicate heat in everyday language often mean something different in science.

The CAPS Grade 7-9 curriculum emphasises heat transfer, energy and insulation, but these remain abstract and difficult concepts for students. The salient aspect of triadic dialogue (Lemke, 1990) – classroom exchange occurring as a triad of “moves” comprising a teacher question, followed by a student answer and then closing with a teacher evaluation limits opportunities for students to “talk science” and engage in collaborative inquiry through true dialogue.

Semiotic perspectives that explore classroom learning are based on semiotic affordances – the meanings that are communicated through different modalities (Kress et al., 2001). Modalities refer to how modes of communication (e.g. spoken words, written text, visual images, physical artefacts, and gestures) influence meaning making (Jewitt et al., 2001). One recent development has been on how the sense of touch may serve as a mode (Bezemer & Kress, 2014). An interesting semiotic dynamic of this study is that without coordinating any visual mode to communicate “heat”, learners will rely heavily on touch to make meaning about thermal phenomena.

**Methods**

The research context is Grade 7-8 general science education at two township schools in the XXXX. Grade 8 learners are selectively recruited to one of the schools based on high achievement and talent, while the Grade 7 learners can be considered as a more typical township class. Thermal cameras render the invisible infrared world as a visual mode of communication in the form of a colour scale where warmer objects appear red and colder objects blue (Fig. 1). Thermal cameras afford the opportunity to visually experience heat conduction as the “flow of heat” between objects of different temperatures. Various semiotic affordances of multimodal interaction with the camera include visual, tactile, verbal and actional modes of communication.

![Figure 1. Respective heat conducting and insulating properties of metal and wood demonstrated by the image on the thermal camera.](image)

A FLIR C2 camera (Fig. 1) was used in predict-observe-explain (POE) (White & Gunstone, 1992) activities consisting of pouring hot water into cups of different material and thickness, and engaging hand contact with wood and metal. Author XX participated in the dual role of facilitator and co-
researcher. POE activities, camera actions, group and teacher-learner interactions, were video and audio recorded and transcribed in English. A multimodal semiotic analysis explored the interplay of different modalities on pupils’ meaning-making (e.g. Jewitt et al., 2001), informed by insight from XX’s 19 years of experience as a teacher trainer and teacher in the township context.

Results and Discussion

Results focus on selected POE episodes. In the opening episode, Grade 8 learners are asked to predict which of a piece of wood or metal knife is the coldest, followed by which one feels colder:

L1: …the metal knife is the, is much colder than the wood because the metal knife is a good absorber or should I say a conductor of any temperature around it. So, I think it absorbed the room temperature and I think it’s the one that is colder than the wood.

The exchange continues:

XX: Do you also share the same view?
L3: No, I think they are both at the same temperature… at the same room temperature […]
L4: I think the wood is colder than the metal knife because the wood cannot conduct heat well…

Three distinctly different predictions emerge from the learners – a highly dynamic POE situation that reveals various student lines of reasoning for justifying them.

In an observe episode with Grade 7 learners, the thermal image is projected onto a screen, and XX points the camera to the wooden piece:

XX: …what do you see on the board? L3: Blue
L2: Blue
XX: … what does it say about the heat?
L3: It’s cold
L4: It’s cold, it’s 24
XX: We talk of it as cold… ok, and then what does it say in terms of the temperature? Have a look at the temperature.
All: 24 degrees Celsius

The learners readily coordinate the rendered colour and temperature numerals on the screen, and interpret the wood as being cold due to the blue colour. From a semiotic perspective (Kress, 2010), blue is associated with cold by convention (e.g. markings on taps). The datum represents rapid transduction between modes, from colour, the perceived feeling of cold, to the visible values, and all communicated through spoken language.

In an episode explaining that the knife and wood had the same temperature as the room (ca. 25 °C), Grade 7 learners do not accept this explanation. XX views the objects with the IR camera again:

XX: …the temperature of these objects is the same! [learners smile] It is the same! Isn’t it the same…?
L4: I can’t believe...

While XX points out that the objects have roughly the same temperatures, the learners acknowledge the observation, but L4 expresses his clear disbelief.

Conclusion

This study demonstrates learners’ coordination of multiple semiotic resources, including dynamic coloured thermal images, visual numerals, spoken language and touch. As replicated in a Swedish context, the pupils’ reasoning is dominated by the sense of touch. The study supports Ramnarain’s (2014) findings that inquiry-based teaching approaches are challenging in the township context. However, the example of the particularly committed Grade 8 learners shows that Lemke’s (1990) true dialogue is possible to achieve.

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A METHODOLOGICAL FRAMEWORK FOR EXPLORING SENIOR PHASE NATURAL SCIENCE TEACHERS’ PEDAGOGIC COMPETENCIES

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This study seeks at investigating how senior phase Natural Science teachers’ pedagogic competencies (CK, PK and PCK) could be strengthened in the implementation of elements of CAPS curriculum in Ngaka Modiri Molema district, one of the four districts of the North West province, particularly in the strand, Matter and Materials. Natural Sciences comprise of Life Sciences (Life & Living), Chemistry (Matter and Materials), Physics (Energy & Change) and Geography (Planet Earth and Beyond). Of the four listed above the lowest performed is Matter and Materials, which comprise of the chemistry topics that most of the NS teachers, especially those who did not specialise in Physical Sciences find it difficult to teach. This is explanatory- sequential mixed methods study utilises a number of instruments that test senior phase Natural Sciences teachers’ pedagogical competencies (CK and PCK) are to be administered. First, a questionnaire to survey teachers’ perceptions of the CAPS curriculum was developed, validated and piloted among the 75 teachers. This instrument has ten themes which were created from CAPS elements extracted from Natural Sciences grade 7-9 CAPS document. The elements of CAPS guide teachers’ classroom practices expected of them. A four-point Likert scale which ranges from Strongly Disagree to Strongly Agree is used. The preliminary results indicate that teachers accepted CAPS curriculum. However, on the area of the questionnaire where teachers had to express their opinion of CAPS elements in relation to their classroom practices, most of them expressed their wish to be developed or strengthened on content knowledge (CK) to match the level of depth of certain topics, particularly on Matter and Materials strand, which encompass chemistry area of Natural Sciences, and pedagogic content knowledge (PCK) as some topics are difficult to teach.

Once the other stages of data collection are completed, a professional development intervention workshop shall be undertaken to strengthen teachers’ pedagogical competencies (CK and PCK) in their topic of concern. The intervention shall be conducted as soon as interviews and lesson observations are analysed. It is hoped that this shall take place during the second term of school calendar which is the term in which Matter and Materials is taught. During intervention workshops the following instruments shall be self-administered; namely the CK and PCK instruments. First as a pre-test for diagnosis of the pedagogic competencies (CK and PCK), then remedy. Secondly as post-test to establish the effect of intervention workshops. The purpose of this paper is to outline the methodological framework in this study to address the following research questions:

i) What are the challenges (if any), and the nature and scope of pedagogical competencies (CK, PK and PCK) exhibited by the grade 9 Natural Science teachers in teaching from the CAPS curriculum?
ii) To what extent do CK, PK and PCK based intervention affect the pedagogical competencies perceived challenging by grade 9 Natural Science teachers in teaching and assessing from the CAPS curriculum?
AN APPROACH TO GAUGE INTEREST AND FACILITATE PARTICIPATION IN SCIENCE AMONG SOUTH AFRICAN HIGH-SCHOOL STUDENTS

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It is well-known globally that investment in Science Research and Development will result in economic growth (Schulze & Lemmer, 2016). But, the latest research in South Africa has indicated that the majority of students are uninterested in selecting Science as a first choice at secondary school, and consequently as a field for their career later on. Maths and Science at the level of high-school act as gate-keepers to qualifications in Science at higher learning institutions. Therefore, not selecting Maths and Science as part of one’s school curriculum places learners at a distinct disadvantage in terms of the range of tertiary qualifications accessible to them when they enter university. Thus, the students’ selection of subjects at school could affect their career choices.

Moreover, literature has reported repeatedly that South African learners have the poorest literacy and numeracy skills according to global comparisons (Juan & Visser, 2017; Reddy et al, 2015). Findings from these reports bring into question the importance that students and teachers place on the learning of Science-related subjects. It is crucial to focus on the support and challenges students experience in terms of their school and family background, peer engagement, and their perspective for their fit within the field of Science because these factors impact on the development of the students’ Science identity. If current trends in Science in the South African landscape continue, the research and development industry in South Africa will be negatively impacted.

Apart from this, South Africa’s historic apartheid past caused for little sustained focus on Maths and Science at many public schools that catered for the non-white populations, and teachers teaching at these schools were not usually adequately qualified. Therefore, to address social-justice and educational transformation it is important to probe further into the deep-seated reasons for a) students studying Science at school, b) students pursuing of a Science-related qualification after secondary schooling, and c) students leaving or remaining within a Science career once they graduate.

This study therefore sets out to answer the following research question:

‘To what extent do students who aspire to be employed within Science remain within this domain once they have qualified and have entered the labour force of South Africa?’
Objective One: To examine the level of interest students in high-school have towards a career in Science, and how they perceive their level of access into Science-related qualifications at a tertiary institution and in terms of employability once they qualify.

Objective Two: To critically investigate the factors which attribute to the levels of success of students in their undergraduate studies in Science, and to establish the reasons for attrition.

Objective Three: To ascertain the extent to which graduates who have completed their Honours qualification in Science remain within this domain once they enter the workforce in South Africa, and the extent to which they perceive their university qualification has enabled them to meet the requirements of their jobs in the workplace.

A questionnaire was provided to grade 10 and 12 Life Sciences learners, another questionnaire was provided to first-years, and a third questionnaire was administered to Honours graduates from 2010-2016. The data for each set of questionnaires was analysed qualitatively, and was coded in order to find themes and trends that emerge from the data.

The first part of the study probes the extent to which Grade 10 and 12 students who are interested in Science are facilitated to continue in this field during their studies at school. Data analysis indicates that while most learners are interested in Science at high-school, and perceive they will receive support from their family to enter into university, the majority (83.5%) of students in the sample are unsure that they would like to pursue a Science qualification. This is a crucial finding since the study sample consisted of students who had selected Science as a subject choice at high-school, and would therefore be part of the potential pool of Science students who could apply to university for qualifications in Science, and thus become part of the workforce associated with the Research and Development Industry. It is essential to understand the influence of teachers on student motivation to learn Science; further research is required in this area.

The second part of the study investigates the factors that influence retention of undergraduates in Biology. The factors investigated include the students’ perception of their academic and social integration, degree and institutional commitment, support services satisfaction, and academic conscientiousness: Significantly, results show that the students’ academic conscientiousness (94%), institutional commitment (81%) and degree commitment (70%) are the most influential non-academic factors. Students perceived challenges in terms of a) not being provided with sufficient information of lecturer expectations, b) limited scaffolding from the university to better prepared students for the learning environment, and for the type and level of assessments at university, and c) levels of isolation from peers and staff. Undergraduates suggested that departments have events so that they can get to know their peers and lecturers, and thus enable students to develop a sense of belonging. The students commented on a need for better communication from the university on bursaries, scholarships, and issues around student protests. Third years were least satisfied with academic integration (66%), social integration (54%) and supportive services satisfaction (28%). This
could be the result of the recent student protests which were rife at the university in recent years. Results in this aspect of the study reflect factors which students perceive as being supportive and as challenges in relation to their academic progress.

The third aspect of this study ascertains the extent to which Honours graduates in Science remain within this domain once they enter the workforce, and the extent to which they perceive their university qualification has enabled them to meet the requirements of their jobs in the workplace. Findings show that most Honours graduates (68%) from Biology remained in Science when they entered into employment, these graduates joined environmental science consultancies (40%), and became a staff member at the university (11%). But, graduates generally found difficulty in finding jobs in the field of Science. While some were employed in teaching of Science at schools (14%), or gaining employment in unrelated fields (31%), they would have preferred to remain within Science when they entered the workforce. The reasons that were cited in relation to moving out of the field of Science are financial difficulties while waiting for a job opportunity in Science, inability to gain employment in Science, more job opportunities in education, and loss of interest in Science. Interaction with staff at the university had an impact on some of the students’ science identity and career choice. Students related that they are getting the generic skills during the course of their university studies regardless of whether they are pursuing jobs in science or not. However, some graduates are questioning whether the department is training them for academia and whether enough content is given to prepare them for the workplace.

It is crucial to gain insight into the students’ perceptions of the challenges and support which they have to meet career aspirations in Science, this is because their sense of fit and belonging are affected by the perception, and thus influences their development of Science Identity.

According to Brickhouse et al (2001) and Gee (1990) Science Identity is based on the student’s views of who they are, what their potential is, and what they aspire to do with regards to a career. Carlone and Johnson (2007) have extended this definition to show that inter-relationships with the world at large also influence the formation of identity. In terms of this study, the students’ perceptions influence the way in which they negotiate the aspirations. Thus here, the formation of Science Identity is used to investigate the students’ aspiration to remain within Science. The results from this study could be used by academic developers to further understand and facilitate student transition and retention at university.

References


PERCEPTIONS OF SELECTED PHENOMENA AMONG EGYPTIAN, BRAZILIAN AND JAPANESE PRE-SERVICE/IN-SERVICE SCIENCE TEACHERS

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Abstract:
The aim of this study is to investigate the nature of worldview presuppositions held by teachers from three different countries in different continents and cultural backgrounds. This is done by investigating, through an in-depth analysis, responses from both in-service and pre-service teachers from Egypt, Brazil and Japan using a comparative lens. Results indicate that teachers hold a multiplicity of worldview presuppositions about diverse phenomena though their scientific worldviews followed by their personal views appear to be dominant.

Keywords: Perceptions, worldviews, phenomena, pre-/in-service teachers

Introduction

The influence of nature of worldview and cultural aspects on subject’s science presuppositions are largely studied and discussed (e.g. Cobern, 1996; 4th Author, et al., 1995). Understanding the students’ and teachers’ cultural conceptions and their roles in teaching and learning science has become one of the most important domains of science education (Duit & Treagust, 2003), as culture has been considered a key aspect of science teaching and learning (4th Author, 1988). It is known that science teachers’ worldviews can influence the way they teach science. Indeed, education in science does not guarantee that science teachers would always teach the scientific view or to guide their students about the weak points of their alternative conceptions (4th Author, et al, 1995).

Considering that socio-cultural aspects strongly influence the way people interpret the world, it is imperative to investigate how science teachers handle or accommodate scientific knowledge in relation to their previous traditional knowledge. From this, we can think over how would their pedagogical practice in school science education be? Still, on a larger scale, how does this take place in different cultures?

Theoretical Framework
The study is underpinned by Kearney’s (1984) worldview theory (KWT) and the Contiguity Argumentation Theory (CAT) (4th Author, 2007a). KWT contends that people’s beliefs control their perceptions, predispositions and behaviours in general. CAT on the other hand posits that people’s perceptions are the products of a dynamic process involving cognitive conflicts, accommodation, assimilation, integrative reconciliation and adaptation—all in an attempt to harmonize with the context in vogue.

Placing this theoretical framework in the field of science education, Gauch (2009) argue that presuppositions and reasoning of science can and should be worldview independent, a plethora of empirical evidence is in conflict with this view.

Therefore, the present article aims to investigate the nature of worldview presuppositions held by science teachers in three different cultures.

**Purpose of the study**

The purpose the study is to explore: (a) the worldviews presuppositions held by science teachers; (b) compare the patterns of worldview presuppositions within each country and across countries; and (c) determine the sources of the worldview predispositions.

**Methodology**

**Sample:** Worldview presuppositions were obtained from 50, 62 and 32 science teachers (pre-service and in-service), who answered questionnaires (valid when completely and adequately filled out) from Brazil, Egypt and Japan, respectively. The instruments were evaluated and approved previously by Research Ethics Committees from each country. Although we aimed of at least a sample of 50 subjects per country, however, it was not possible to establish, a priori, the size of the sample that would be necessary to obtain good results, since several difficulties stood on our way; one being the issue of obtaining ethical clearance.

**Instruments:** The instrument used for assessing the pre-service/in-service science teachers’ understanding of diverse phenomena consists of ten fictitious stories, analysis of five only are presented in this study. The main aim of these fictitious stories was to elicit participants’ ideas about their scientific knowledge. Participants expressed agreement, disagreement or no opinion as well as indicated the sources of their worldviews for each story. Participants were also asked to state the source of their views. They were to select from four main sources: Science = S; Indigenous knowledge = I; Cultural beliefs = C; Religious belief = R; and Personal view = P.

To attain high validity, the questionnaire was subjected to a series of revisions and rated 1-5 by two sets of 12 independent experts (1 = poor or unclear item and 5 = Excellent item). The inter-rater coefficients on the questionnaire before it was administered to the subjects ranged between
0.93 and 0.99 using a modified Spearman-Rank Difference Formula. An interview schedule to be derived from the subjects’ responses to the questionnaire would be administered later to 10 subjects per country.

The stories analysed are the following and the results are presented in the next section:

Story 1: There is a place in the Atlantic Ocean called Bermuda Triangle. In that place many planes and ships have vanished without any trace of their wreckage.
Story 2: Peanut seeds kept in a box containing magnets were found to germinate faster than those not kept in the box.
Story 3: Often animals are faster in perceiving changes in the environment than humans. For example, animals will start to run away for shelter before the occurrence of a strong wind, rain or disasters.
Story 4: Many scientists believe that the universe (including the earth) occurred by chance and has been undergoing continuous evolution. However, many people believe that the universe (including the earth) was created by God or a Supreme Being.
Story 5: A football referee was struck down by lightning during a rainy match. He was the only one struck down by lightning.

**Preliminary Findings**

In Story 1, the responses of the subjects in three vastly different cultures from three separate countries believe that the disappearance of the ships and planes was a mysterious event. However, their strong views (75%) on this were based on their personal opinions than their scientific knowledge.

Their views on Story 2 concerning magnets speeding the growth of seeds were rather muffled most probably because of the poor quality of this item. However, the subjects were strongly opposed (79%) to the notion that the speedy germination of the seeds was caused by the farm or soil goddess.

The subjects’ views regarding Story 3 about animals possessing sensitive body parts (83% and 73% respectively) were most probably derived from their scientific knowledge. Similarly, their views on Story 4 about the origin of the universe were largely based on the scientific Big Bang Theory (68%) but less on evolution (57%). In the same vein, their views on Story 5 about the referee struck by lightning were probably based on their scientific reasoning than spiritual or mystical beliefs.
Table 1: Mean percentages of teachers’ worldview presuppositions about diverse phenomena in Brazil, Egypt and Japan

<table>
<thead>
<tr>
<th>Terms</th>
<th>Worldviews presuppositions</th>
<th>A</th>
<th>D</th>
<th>DK</th>
<th>S</th>
<th>I</th>
<th>C</th>
<th>R</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. People believe that the planes and ships are caught up in the world of the dead.</td>
<td>Agree: 78%</td>
<td>68</td>
<td>18</td>
<td>44</td>
<td>5</td>
<td>7</td>
<td>3</td>
<td>25</td>
<td>56</td>
</tr>
<tr>
<td>People believe that pirates might have stolen the planes and ships.</td>
<td>Agree: 65%</td>
<td>65</td>
<td>19</td>
<td>22</td>
<td>4</td>
<td>9</td>
<td>1</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>People believe that gods/goddesses were probably responsible for the disappearance of the planes and ships.</td>
<td>Agree: 61%</td>
<td>61</td>
<td>13</td>
<td>24</td>
<td>3</td>
<td>6</td>
<td>23</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>People believe that it must be one of those strange and mysterious things in the world.</td>
<td>Agree: 75%</td>
<td>75</td>
<td>19</td>
<td>6</td>
<td>26</td>
<td>3</td>
<td>7</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>People believe that the planes and the ships have been taken away by the witches.</td>
<td>Agree: 60%</td>
<td>60</td>
<td>7</td>
<td>41</td>
<td>9</td>
<td>4</td>
<td>0</td>
<td>97</td>
<td></td>
</tr>
</tbody>
</table>

A = Agree; D = Disagree; DK = Don’t Know; Sources of worldview - S = Science; I = Indigenous Knowledge; C = Cultural beliefs; R = Religion; P = Personal belief.

Table 2: Percentage of teachers’ worldviews according to country

<table>
<thead>
<tr>
<th>Responses to Story 1</th>
<th>Country</th>
<th>A</th>
<th>D</th>
<th>DK</th>
<th>S</th>
<th>I</th>
<th>C</th>
<th>R</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>People believe that the planes and ships are caught up in the world of the dead.</td>
<td>Brazil</td>
<td>6</td>
<td>84</td>
<td>10</td>
<td>40</td>
<td>7</td>
<td>11</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>Egypt</td>
<td>26</td>
<td>48</td>
<td>25</td>
<td>60</td>
<td>7</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>9</td>
<td>72</td>
<td>19</td>
<td>32</td>
<td>6</td>
<td>6</td>
<td>0</td>
<td>56</td>
</tr>
</tbody>
</table>

A = Agree; D = Disagree; DK = Don’t Know; S = Science; I = Indigenous Knowledge; C = Cultural beliefs; R = Religion; P = Personal belief.

Our preliminary findings suggest that despite the subjects’ cultural differences and indigenous beliefs, their worldviews on all the five stories indicate that they were influenced mostly by their scientific knowledge and to some extent their personal beliefs (Tables 1 & 2). This however, as has been pointed out in several earlier studies, does not imply that they are completely free of other worldviews.

Conclusion
In light of these preliminary findings, we agree with Gunstone and White (2000) that teachers should point out to their students when a particular worldview is most appropriate, when it is needs to be critiqued or accepted if found to be valid as commonly done by the scientific community, and to know how to connect what they learn in the science classroom to their real lives outside school environment. Therefore, since current and future science teachers hold non-scientific worldviews, these results call attention to their real and immediate need for reflections not only by these subjects but by the science education community in general.

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BEADS AND BEADWORK (CULTURAL ARTIFACTS) AS MEDIATORS OF LEARNERS’ AGENTIC CONSTRUCT IN THE SCIENCE CLASSROOM: A Case for Situated (Place-Based, Indigenized) Learning.
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Introduction

In between the teacher’s teaching and the learners’ learning of abstract science concepts in the classroom appears to be a sort of interface where the learner either understands these concepts or not. Where learners are indigenous, and the subject matter is abstract, indigenous learners seem to face challenges in understanding westernized science when their lived-world is undervalued and learning context is unfamiliar with them. It is therefore pertinent for teachers to relate science to the learners’ lived-world (learners’ worldview) (Ogunniyi, 2013) in order to co-create intriguing and lasting experiences for both the teacher and the learner. Using materials found in the learners’ lived world can mediate the understanding of abstract science concepts by indigenous learners and the transformation of learning experiences from abstract to more concrete experiences as learners become more active in their learning process. This paper tends to explore the affordances cognitive mediation with the use of beads and beadwork (cultural artifacts) brings the learners in the life sciences classroom. In what ways are learners afforded when cultural artifacts are used to learn.

Literature review

Indigenous learner’s performances in science subjects have not been encouraging. This could be as a result of the abstract nature of westernized science. Mediating learners understanding of abstract science concepts by alluding to the learners’ lived world (beads and beadwork) can concretize concepts for learners. This transformative experience because of the mediation can provide learners with emancipative experiences that turn un-intiguing pedagogy to an intriguing one. Therefore, not alluding to learners’ prior knowledge (learners’ culture) can adversely affect learners’ understanding of scientific concepts. According to Ogunniyi and Mushayikwa (2015), there is nothing wrong in alluding to the learners’ indigenous knowledge to teach them science concepts.

Theoretical framework

According to Bourdieu (1977), if an agent has more capital, it has more opportunity to be more successful in an endeavour than the agent with less capital. The use of cultural artifacts (beads and beadwork) generated cultural capital as well as social capital (bonding through interactions and
learning in groups). Beads and beadwork (cultural artifacts) also brought about symbolic capital as learners who were successful in their task were seen collectively forming identities of successes which spurred others as a result of positive vicarious experience, to become successful in their tasks. After being successful in simple tasks, learners became enabled to solve more complex tasks (cognitive capital). The accumulation of these capitals generated in the learner’s agentic constructs that enabled them to co-create understanding of life sciences concepts together with the teacher.

Methodology

This research is interpretive, incorporating a case-study methodology. The study was carried out in a peri-urban metropolitan city in South Africa. The teachers (four) experiences during the professional development and training workshop, their teacher-centered classrooms, and mediated the classroom, where they taught learners the structures of simple and complex organic molecules were recorded on video. Learners’ interactions with the teacher where they were taught the creation of culturally related instructional models (CRIM) of simple and complex organic molecules in the life sciences classrooms were also recorded on video. Open ended questionnaires and field notes were also used to elicit their experiences. Data was transcribed and interpreted as themes and categories were formed. Categories formed from both classrooms (traditional teacher-centered and the classroom where culturally related instructional models (CRIM) were used to teach simple and complex organic molecules) were compared and contrasted.

Findings

Transfer and transformation of capitals

After the professional development and training workshop, the teachers’ awareness on the use of capitals as resources in the classroom to enhance their pedagogical practice became heightened. A teacher (Mbali) getting to the classroom found few learners wearing beads on their wrist.

Mbali said, “Wao, see them put the beads on”. This is the same class Mbali taught with the traditional teaching method where she spoke for most of the lesson, and learners were passive in their learning process as they either responded in a one-word answer or did not answer at all.

Also embodied in the learners which they transferred to the classroom was their sense of communalism (social capital). As the teachers introduced the lesson to be taught with beads and
beadwork (cultural artifacts), learners without further instruction changed their sitting arrangements from rows to groups. They formed groups of three and four as interactions further generated bodily interactions, smiles and movement which strengthens Boykins (1986) position on the Black Ethos as characterized by spirituality, affect, harmony, orality, social perspective of time, expressive individualism, communalism and rhythmic-movement expressiveness. Learners’ interactions influenced learners’ know-how of the lesson as the learners engaged their local language to explain to themselves the lesson content. This is despite the norm in the westernized science classroom where learners’ speaking of local languages are restrained as seen in the traditional teacher-centered classroom. Learners saw their local language as a resource to enhance their understanding which is a form of cultural capital in the mediated science classroom.

During the lesson where culturally, related instructional models (CRIM) of simple and complex organic compounds were used, as soon as their tasks where approved correct by the teacher, the learners in the group generated collective effervescence and form symbolic capital. To the other learners whose tasks have not been approved to be correct, seeing these group of successful ones, strive to become successful in their tasks. Towards the end of the CRIM lesson, all groups had formed identities of successes in the life sciences classroom. Learners became energized to create the next complex organic compounds. In attempting the next organic compounds, learners became enabled by the accumulation of the three capitals (cultural social and symbolic) to generate cognitive capital needed to attain the state of zone of proximal development (ZPD) and subsequently solve harder tasks. The embodiment of the increased positive emotional energy also seems to increase learners’ self-efficacy as success begat success; hence the learners wanted to construct more complex structured organic compounds. The process involved in enabling learners understanding of the abstract life science concepts were energized by the transformation of capitals available in the learners’ lived world. Energization becomes the process of and procedures for kindling learning by an MKO (the teacher) through vicarious learning (Otulaja & Fakoyede, 2018).

Beads and beadwork (cultural artifacts) apart from its aesthetic properties, became cognitive objects as learners further suggested other various ways their learning could be enhanced by the use of beads and beadwork. Learners suggested that beads can be used to (i) represent structures of various elements, molecules, saccharides, disaccharide, polysaccharide, monosaccharide, and other formula in science (ii) enhance their ability to learn to do new things, make designs and experiment in the science classroom;(iii) teachers should continue to use beads and beadwork (cultural artifacts) to teach learners in the science classroom because it enables learners to be creative, to understand and make learning easier. Taking cognizance of these learners’ suggestions and their leap from attempting simple tasks to solving more complex tasks strengthens the process of cognitization as a process and procedure of cognitizing aesthetic non-cognitive object to become cognitive tools. The use of cultural artifacts for cognitive purposes appeared to have enhanced learners’ understanding of simple and complex organic compounds in the life sciences classroom.
The enablement of learners who were passive in the teacher-centered classroom by capitals gained in the CRIM class further enhanced learners’ expressiveness as they were seen co-teaching (peer tutoring), co-assessing each other, imitating and observing each other, peer complimenting and motivating, peer questioning and questioning the teacher, peer trans languaging and peer identity of successes formation. These are agentic constructs that the learners became enabled to perform as they co-created the enabling context for their own understanding of simple and complex compounds opened up the possibilities for improved performance in life sciences. The use of beads and beadwork (cultural artifacts) became mediators in the interface between the teachers’ teaching and learners’ know-how as learners became agentic in their expression.

Conclusion

Learners engagement with culturally related instructional models (CRIM) in the science classroom assisted in creating an enabling experience that is culturally congruent (Ladson-billings, 2001), culturally productive (Vygotsky, 2001) and culturally responsive as indigenous learners understanding of life sciences concepts were enabled by the interplay of capitals. The articulation extends the Bourdieusian’s concepts of capital and Engestrom concept of activity theory.

References


MAKING RESEARCH MORE ACCESSIBLE FOR FIRST-YEAR UNDERGRADUATES
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Introduction

Science often is taught through prescriptive, “cookbook” laboratory activities which do not teach students about how scientific knowledge is created. Many universities are replacing traditional laboratory courses with course-based undergraduate research experiences, or CUREs, to help improve student persistence in science. As students are given increased freedom to devise their own research questions and investigations, CUREs authentically resemble the work of scientists. In authentic CUREs, neither students nor instructors know what the results of the research will be, and the findings are relevant to the professional scientific community.

CUREs accommodate a greater number and more diverse group of students than traditional mentored undergraduate research experiences (UREs). Typically, students selected for UREs are high-achieving and/or upper-division STEM majors already motivated to succeed in their field, as illustrated in Lopatto (2007). In comparison to UREs, CUREs engage first-year undergraduates with different abilities and backgrounds who may not yet have decided on a major. These first-year students also are susceptible to dropping out of STEM majors as Seymour and Hewitt (2007) found in their landmark study. Therefore, due to their inclusivity, CUREs have the potential to increase the number and diversity of students pursuing STEM degrees (Russell et al., 2007; Eagen et al., 2013; Graham et al., 2013).

We developed and implemented a CURE in an introductory biology laboratory course for first-year students at a research-intensive university with funding from the Howard Hughes Medical Institute (HHMI). The course brought faculty and their research into the classroom where students conducted an experiment of their own design within the realm of the faculty instructor’s research program. Students had freedom to ask their own questions, form hypotheses, and then develop research projects to test their hypotheses. Student-generated research questions and experimental designs gave this CURE a high level of authenticity.

The CURE labs were taken in place of the traditional two-semester introductory biology lab course sequence. In a CURE lab, groups of six students worked on a research project under the guidance of a teaching team. The teaching team was composed of a faculty member, a graduate student, and an undergraduate facilitator. Each section of up to 24 students met once a week for three hours. Half-
way through the semester, students switched teaching teams and research areas, so that they were exposed to four different faculty and their research over the academic year.

We had three main goals for the CURE biology laboratory courses: 1) teach students about the nature of science and research; 2) expose students to what scientists do and to research as a career; and 3) engage research faculty in teaching first-year students.

**Methods**

To assess student academic outcomes after taking the CURE labs, we collected data for students who took traditional introductory biology labs (control group) and the CURE labs (treatment group) over a span of 10 years. Data included; gender, race/ethnicity, SAT (or ACT equivalent) standardized test scores (used for college admissions in the U.S. to gauge students’ readiness for college academics), matriculation term, matriculation majors, introductory biology lab course taken and during which term, participation in special academic programs, research course credits earned subsequent to enrollment in introductory biology labs, graduation term or last term enrolled, latest UM GPA, undergraduate degrees earned, majors at graduation or latest majors, and graduation with honors.

We used propensity score matching to identify an unbiased, control group of students from the traditional introductory biology labs. Propensity scores correct for course selection bias and reflect the probability that a traditional lab student might have taken a CURE lab (West et al., 2008; Rosenbaum and Rubin, 1983, 1984 in Schultz et al., 2011). We matched students on variables that may have affected the outcomes examined, including SAT (or ACT equivalent) score, STEM major at matriculation, gender, and race/ethnicity, as well as graduation status to ensure each group was equal in numbers of graduated and non-graduated students. We matched groups using the Propensity Score Matching program for SPSS version 3.0.4 (Thoemmes, 2012). This resulted in a control and treatment group of similar sizes, demographic make-up, SAT (or ACT equivalent) scores, numbers of students matriculated as STEM majors, and graduation status.

We analyzed the effect of the CURE labs on outcomes associated with student engagement in research, progress towards a STEM career, and academic achievement. To examine the relationships between these outcome variables and predictor variables, we used hierarchical logistic regressions to compare the propensity-score matched groups. This method allowed us to control for effects of the matching variables correlated with the outcomes. In the first step of the model, we used gender, race/ethnicity, and SAT score (the matching variables). Then whether students participated in traditional or CURE labs was included in the second step. The outcome variables we analyzed were subsequent enrollment in research credit courses, major at graduation, time to graduation, and graduation with honors.
Results

Participation in the CURE labs had a significant effect on the likelihood of having subsequent individual research experiences, as measured by enrollment in research course credits ($\beta = 0.421$, Wald $\chi^2 = 8.164; P = 0.004$). After accounting for the significantly positive correlations of STEM major at matriculation ($\beta = 2.131$, Wald $\chi^2 = 16.316; P \leq 0.0001$) and SAT score ($\beta = 0.003$, Wald $\chi^2 = 16.270; P \leq 0.0001$), CURE lab students were 1.5 times more likely to earn research course credits than control group students who took the traditional lab (O.R. = 1.534, 95% CI [1.141, 2.034]). Overall, 38% of CURE lab students and 29% of traditional lab students earned research credits. The CURE labs also had a significant effect on the likelihood that students graduated with a STEM major ($\beta = 0.445$, Wald $\chi^2 = 7.493; P = 0.006$); CURE lab students were 1.6 times more likely to graduate with a STEM major compared to traditional lab students (O.R. = 1.560, 95% CI [1.391, 2.756]). Overall, 75.6% of CURE and 69.2% of traditional lab students graduated with a STEM major. Participation in the CURE labs were significantly correlated with time to graduation ($\beta = 0.447$, Wald $\chi^2 = 10.924; P = 0.001$), with CURE lab students being 1.6 times more likely than traditional lab students to graduate in four years or less (O.R. = 1.564, 95% CI [1.200, 2.040]). In the CURE lab group 81% of students graduated in four years or less, whereas 70.3% of students in the traditional lab group did. The CURE labs had a positive effect on graduating with honors, even after accounting for SAT score ($\beta = 0.535$, Wald $\chi^2 = 12.011; P = 0.001$). Students who took the CURE labs were 1.7 times more likely to graduate with honors than traditional lab students (O.R. = 1.707, 95% CI [1.262, 2.311]). Because graduation with honors was significantly correlated with GPA (Pearson’s $r = 0.708$, $P \leq 0.0001$), we can infer that CURE lab students were more likely to graduate with a higher GPA than traditional lab students. Overall, 10% more CURE lab students graduated with honors than traditional lab students.

Discussion

We found that participation in the CURE labs increased students’ participation in subsequent UREs, persistence in STEM majors, and academic performance even after accounting for other factors that likely influenced those outcomes. Outcomes were almost entirely unaffected by gender and race/ethnicity.

The CURE lab model allows for a high level of authenticity. Authenticity may be created through students’ freedom to ask their own questions, design experiments, and participate in discovery of new knowledge that potentially could contribute to their instructor’s own research. These course attributes may give students responsibility for their own learning and a sense of personal investment, which could result in project ownership (Hanauer et al., 2012; Hanauer and Dolan, 2014). Even though 92% of students in both of our propensity-score matched groups declared STEM majors at matriculation, the CURE labs still had a significant positive effect on graduating with a STEM degree. Such an effect may be a factor in keeping minorities and females from leaving science (Hurtado et al., 2009; Schultz et al., 2011; Bangera and Brownell, 2014).
References


THE EFFECTIVENESS OF DAAFLIM IN TEACHING N2-TVET COLLEGE ENGINEERING SCIENCE CONCEPTS
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Abstract
The changes and development of the South African curriculum was influenced by the country’s political transition and the subsequent education reform from apartheid education to Outcome-Based Education. These developments also led to focus on skill development and increased enrolment at TVET colleges. Many lecturers at TVET colleges do not adequate training and experience to teach theory content, because come from a trade background. These and other lecturers find it difficult to enhance the understanding of concepts. This paper combines the theoretical constructs of the Dialogical Argumentation Instructional Method (DAIM) and the Assessment for Learning (AfL) strategies into DAAFLIM that could assist lecturers in enhancing the conception of science concepts.

This study also addresses the disjuncture between curriculum delivery and the crucial role of assessment thereof, in particular formative assessment, which led to the development of the Dialogical Argumentation and Assessment for Learning Model (DAAFLIM). This study sought to determine if there is a significant difference between the N2-students exposed to Dialogical Argumentation and Assessment for Learning Instructional Model (DAAFLIM) and those not so exposed, on the selected science topics.

The theoretical framework of this study is based on Toulmin’s Argumentation Pattern (TAP), the Contiguity Argumentation Theory (CAT) and Social Constructivist Theory. These theories are the lenses used to examine how the construction of knowledge takes during the pedagogical process, especially during formative assessment activities. A quasi-experimental design with a mixed method approach was used involving two N2-Engineering Science intact class groups of which the experimental group received the DAAFLIM intervention strategy. A science achievement test and activity worksheets were used to analyse the collected data both qualitatively and quantitatively. It is believed that the findings of this project should influence the TVET college curriculum developers to make the curriculum content and assessment more relevant to students’ everyday-experiences.

Key words: TVET colleges, dialogical argumentation, formative assessment, engineering science and knowledge construction.

Introduction
In South Africa, since the new political dispensation in 1994, attention has been focused in education on issues related to access, equity, quality and democracy at pre-primary, primary, secondary and tertiary levels. Several authors have also pronounced the need for curriculum change and teaching methodology to make education more relevant to the new South African context and the objectives of the new dispensation. The increasing number of students migrating from previous disadvantaged institutions to previous advantaged institutions reduced the homogeneity of the student populations and necessitates research studies that will help tackle the problem of teaching, learning and assessment in multi-cultural classrooms (Fataar, 1997). The high drop-out rate and students exiting the school system at grade 9 also resulted in an increase of enrollment at TVET (Technical Vocational Education and Training) colleges. Students at these colleges are confronted with unique challenges in terms of learning and assessment which lead to high attrition (Lawrence, 2016). Therefore, there is a need to change the approach towards curricular and pedagogical presentation, which will both support students from diverse backgrounds and improve the challenges of throughput.

Assessment is crucial in any educational process and in many institutions, it is regarded as a very important component. Summative assessment in general is used to determine the success or failure of an educational system. Furthermore, it has become a tool solely for summarizing what students have learned and for ranking students and institutions. Formative assessment requires that evidence of performance or attainment is elicited, interpreted and acted upon during the instruction process.

**Research question**

In this study the following research question was pursued:

Is there a significant difference between the N2-students exposed to Dialogical Argumentation and Assessment for Learning Instructional Model (DAAFLIM) and those not so exposed on the selected science topics?

**Theoretical framework**

This study is underpinned by Toulmin’s Argumentation Pattern (Toulmin, 1958), Contiguity Argumentation Theory (Ogunniyi, 2007) and the constructionist theories of Vygotsky (1978) and Piaget (1936). These theoretical constructs help to shape and guide this research in terms of construction of knowledge. These theories are used to form the theoretical foundation of the Dialogical Argumentation Instructional Model (DAIM) which is “one way of creating teaching and learning spaces where the opinions of learners are valued, thus allowing them to make meaning of science concepts. Learners acquire skills whereby they analyze, evaluate synthesis and apply knowledge acquired to new and unfamiliar contexts” (Langenhoven & Ogunniyi, 2011). However, the DAIM does not extrinsically include assessment strategies, which led to the Dialogically Argumentation Assessment for Learning model (DAAFLIM) which was developed by doctoral students as illustrated in figure 1 (Author, 2015).
DAALIM focuses on concrete ways of assessing the progress and pace of conception during the different stages of the DAIM, by employing Assessment for Learning (AfL) strategies inspired by the work of (Black & Wiliam, 2009). DAAFLIM provides crucial formative feedback to make sure that the objective of the learning activity is met during each DAIM process.

Methodology and sample

A quasi-experimental pre-test-post-test design was used to collect quantitative data. The quantitative aspect of the quasi-experimental design measured the differences between the conceptual understanding of selected science topics of the experimental and control groups (Punch, 2009). The participants were two N2-Engineering Science intact classes of a TVET College. They were 30 students per class from different campuses of the same TVET College in order to avoid possible contamination of data. These class groups were purposefully selected, so that the participants are as similar as possible in terms of achievement of academic results. The researcher taught the experimental group, which was convenient, because he could induct the experimental group adequately in the protocol and practice of DAAFLIM.

The DAAFLIM intervention strategy

The DAAFLIM consists of six stages of cyclic whorls arranged in ever-increasing sizes of a shell, all starting at the nodal point. AfL-strategies are incorporated into the DAIM process in order to get formative feedback at a particular point during instruction. The various stages of DAIM and AfL-strategies are:

Stage 1 (Nodal point):
KWL sheet - At the beginning of a lesson students create a grid with three columns with headings, (1) what they Know, (2) what they Want to know and (3) what they have Learnt. They begin by brainstorming and filling in the first two columns and then return to the third column at the end of the lesson.

Target setting – Students must also set their targets at the beginning of the lesson.

Making aims clear – The lecturer write lesson objectives on the board at the beginning of the lesson and talk to students about why they are studying what they are studying. He contextualises the short-term aims and long-term aims.

Stage 2 (Individual argumentation):

Learners write answers – Students answer the question on the worksheet individually, without interacting with anyone in order to articulate their thinking.

Stage 3 (Group argumentation):

Feedback to group – Within group each student give feedback to the group on their individual responses of the worksheet.

Peer marking - Students mark each other’s responses according to assessment criteria, which will encourage them to reflect and thing about the learning as well as allowing them to see others’ answers. They are also able to identify possible misconceptions.

Constructive controversy – Group members advocate and interrogate the topics of the worksheet in terms of the DAIM-protocol until the group reaches consensus on the best options (Johnson & Johnson, 2003).

Self-evaluation – Students reflect and compare their responses to the responses of the group members and consensus of the group.

Stage 4 (Group sharing):

Group feedback - Groups give feedback to class their consensus, which will help make the teacher aware of learning needs in a manageable way. Group feedback also draws more attention and presents information that has already been ordered and sorted – less repetition for the lecturer.

Stage 5 (Whole class interpretive):

Teacher review - The lecturer leads the review of the lesson using questioning to elicit understanding from students. Focus could also fall upon the effectiveness of the lesson at facilitating learning – i.e. can students think of ways that could be altered to improve their learning. The lecturer also provides model answers and students complete the third column of their KWL- sheet. The teacher could model review by evaluating the lesson in relation to his or her own objectives.

Stage 6 (Focus group reflective):

Thoughtful dialogue - Dialogue between lecturer and individual or group students reflecting on the lesson and give students an opportunity to express their ideas (Black & Wiliam, 2009).

Research instruments
a) **Activity worksheets**

The worksheets were designed based on the findings and recommendations of the preliminary studies and in a way that stimulates discussion and interaction to create interesting and lively debate (Slavin, 1983). Each worksheet covered a particular concept in the form of problem-based and multiple-choice questions. The worksheets include the two most important aspects which is detailed steps for the procedures and being an independent learning tool. It makes it easy to assess and evaluate individual learning gained from group tasks. The activity worksheets included similar exercises that were covered in SAT.

b) **Sciences Achievement Test (SAT)**

The questions were developed based on Bloom’s revised taxonomy (Anderson & Krathwohl, 2001), because organizing objectives helps to clarify objectives for teachers and for students. The SAT consist of four section, which assessed the understanding of the following concepts; SI- units, statics, dynamics and energy.

**Results and discussions**

**Comparability of the groups before the study**

The results in Table 1 were obtained by using the two-group t-test for independent samples to compare the total scores of the groups in the pre-test (Field, 2009). The pre-test results show that the difference between the mean scores (8.37 and 7.42) and the standard deviations (2.76 and 2.83) for the experimental and control groups are very small. The t-ratio value of 1.217 is less than the t-critical value of 2.02 at \( p < 0.05 \), which indicates that the null hypothesis, which expects significant differences between the groups, can be rejected. Therefore, it can be accepted that there was no statistical significant difference between the groups at the pre-test stage of the study, suggesting the comparability of the two groups. However, it can also be assumed that both groups did have some understanding of the selected concepts, because both groups scored a percentage average of 27% and 24% respectively in the pre-test.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean (%)</th>
<th>SD</th>
<th>t-test</th>
<th>Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental group</td>
<td>26</td>
<td>8.37 (27%)</td>
<td>2.76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control group</td>
<td>26</td>
<td>7.42 (24%)</td>
<td>2.83</td>
<td>1.217</td>
<td>0.229</td>
</tr>
</tbody>
</table>

**Table 1: Comparing pre-test scores of the experimental and control group on the SAT**

**Note:** \( t_{critical} = 2.02; p = 0.05 \); \( df = 50 \)

Similarities in the pre-test scores of the experimental and control groups can be assumed to be due to the traditional instructional practices to which they had been exposed before the commencement of the study. A further analysis of the pre-test results indicates that for all the items tested there were no statistical significant differences found. Figure 2 indicates that the students in both groups scored the lowest in Question 3 which assess the concept of moments acting on a horizontal beam.
The highest scores were achieved in Question 1, by the experimental group, where students had to recall and convert SI-units of quantities. The control group scored highest in Question 4, which assess their knowledge of energy. The reason for the high scores in Questions 1 and 4 could be because the students have dealt with these concepts in the N1-Engineering science course.

Typical responses in the pre-test indicating that most concepts were new to the students were:

**Question 1 (SI-units and Conversions)**
Student E5 provides the SI-unit of acceleration as “m/s” instead of m/s2. Student E7 multiplied instead of divide the distance, 0,065 m, by a hundred to convert it to centimetres. Students E19 did not do any calculations to convert mass to weight, she assumed that the mass and weight is the same in quantity, only the units differ, giving the weight as 45 N. Some of the students were not aware not that the Moon has a lesser gravitational force than Earth.

**Question 2 (Interpreting graphs)**
Student E6 drew a straight-line graph without showing the constant velocity part. Student E4 drew the incorrect graph without appropriate titles and labels. Student E9, on the other hand, has a correct graph with incorrect labels. Student E21 plotted the points incorrectly.

**Question 3 (Moments on a beam)**
Student E5 cannot determine the distance between the force and fulcrum for most of the moments. Student E18 identified the direction of the moments incorrectly. Student E20 could not proof that the beam is in equilibrium, using Newton’s Third Law of motion. Many students did not answer this question, especially the last part where they had to determine the components of a vector.

**Question 4 (Conservation of energy)**
Most of the students could calculate the potential energy of the brick at the top, but was unable to determine the velocity of the brick just before it reached the ground. However, the majority were able to differential between potential and kinetic energy.

**Comparing the pre-test and post-test responses**

Table 2 reflects the pre-test and post-test scores obtained by the experimental group in the SAT. The null hypothesis which expects no statistical significant differences between the pre-test and post-test scores of the experimental group can be rejected, because the t-ratio value of 11,170 is greater than the t-critical value of 2.02 at p < 0.05. This indicates a statistical difference between the pre- and post-test results of the experimental group.

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Experimental Group (N = 26)</th>
<th>Control Group (N = 26)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
</tr>
<tr>
<td>Mean(%)</td>
<td>8.4 (27%)</td>
<td>19.8 (64%)</td>
</tr>
<tr>
<td>SD</td>
<td>2.76</td>
<td>4.46</td>
</tr>
<tr>
<td>t-test</td>
<td>11.170*</td>
<td></td>
</tr>
</tbody>
</table>

$tcritical = 2.02; p = 0.05 ; df = 50; (*)$ statistical significant difference

The t-test results indicate a significant change in the means of the pre-test and the post-test, thus it is safe to assume that the experimental group did improve their understanding considerably on the selected concepts in the SAT. The assumption could be that the improvement of the experimental group in their understanding can be attributed to the DAAFLIM instruction model that they received.

As in the case of the experimental group, there was also a statistical significant difference between the pre-test and post-test scores of the control group as reflected in Table 2. There is also a significant increase in the means from the pre-test to the post-test. Thus, the traditional instructional method used in the control group did also produce an improvement in the performance of the group relative to the selected concepts, but to a lesser extent compared to the experimental group. Judging by the means of the pre-test for the experimental group (8.37) and the control group (7.42), it suggests that there was basically no difference at the start of the study. However, the post-test mean scores suggest a significant difference in the scores of 3.93 (13%). The smaller standard deviation of the pre-test and the bigger standard deviation of the post-test of both groups indicate there is a greater variability at the post-test stage.

**Comparing the groups after the study**

Table 3 reflects the post-test results of the experimental and the control group, which reveals a t-ratio value of 3.253 obtained against a t-critical value of 2.02 at p < 0.05. Thus, the null hypothesis expecting no statistical significant difference between the two groups is rejected. This indicates that the DAAFLIM instructional method used in the experimental group classroom is more effective than the traditional expository method of instruction used in the control group classroom. The difference between the pre-test and post-test mean scores for the experimental group is 17.4 (56%) and for the
control group is 9.0 (29%), which is indicative that the experimental group has experienced a greater conceptual improvement. Although the experimental group outperformed the control group with a difference in the post-test scores of 3.93 (13%), it is worthy to notice that the control group also improved with 9.0 (29%).

Table 3: Comparison of the post-test scores of the groups in the SAT

<table>
<thead>
<tr>
<th>N</th>
<th>Mean</th>
<th>SD</th>
<th>t-test</th>
<th>Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experimental group</td>
<td>26</td>
<td>19.85 (64%)</td>
<td>1.49</td>
</tr>
<tr>
<td></td>
<td>Control group</td>
<td>26</td>
<td>15.92 (51%)</td>
<td>1.41</td>
</tr>
<tr>
<td></td>
<td>Difference</td>
<td></td>
<td>3.93 (13%)</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Note. tcritical = 2.02; p = 0.05; df = 50; (*) statistical significant difference

Further comparison of the pre-test and post-test results in terms of the selected concepts reveals additional information about the change in performances of the groups from the pre-test to the post-test stage as indicated in Figure 3. The performance of the students ranges from 4.67 to 5.60 for the experimental group and 3.17 to 4.42 for the control group at the post-test stage.

Fig. 3: Experimental and control group post-test percentage per question

The scores for Question 3, which requires students to calculate the moments of forces acting on a horizontal beam, attracted the least valid responses for both groups in the pre-test. This suggests that the students found it very difficult to answer this question compared to the other questions at the start of the study. In the pre-test the experimental and control groups scored 7% and 10% respectively for Question 3, suggesting that the students relate poorly to applying the law of moments at the start of the study. The performance for this question improved to 45% and 67% respectively, suggesting substantial improvement. In the post-test Question 2, requiring the interpretation and calculations of a graph of motion, both groups scored the least, suggesting that it was the most difficult concept to master.

Conclusion

This study focused on a relatively small sample and formative assessment which is taken for granted by many educators; however, it is an integral part of an instructional process. The DAAFLIM
intervention could improve the efficacy with which educators navigate the pedagogical space of the science classroom in a way that thinking, talking, sharing, learning, teaching, reflection, mediation and research creates spaces for understanding. The findings of this study revealed that DAAFLIM is effective and suggest that it can improve learner conception and performance.

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Abstract

This case study is based on quasi-experimental design in which 40 first year pre-service science teachers (experimental group) was exposed to problem solving skills using a Dialogical Argumentation Instructional Model (DAIM). The control group on the other hand was exposed to traditional instruction. An analysis of the data derived from the subjects’ responses to a Physical Science Achievement Test showed the experimental group significantly outperform their control group counterparts on problem solving in classical mechanics.

Keywords: Pre-service teachers, Problem-solving, dialogical argumentation instructional model, physical science achievement test, conceptual resources

Introduction

One of the goals of problem-solving is to enhance learners’ ability to digest, critique, evaluate, analyse and synthesize scientific facts, concepts and generalizations as well as appreciate socio-scientific issues (Jonassen, 2011). Equally important in this regard are the opportunities created through problem solving to share with peers, clear doubts, reflect and even change one’s view in the face of a more convincing arguments (Ogunniyi, 2007a). In South Africa, for example, teachers have the tendency to cover all the topics in the syllabus often at the expense of learners’ clear understanding of the critical issues involved (Jackson & Rothmann, 2005).

It was in light of the foregoing that we explored the potential of DAIM for enhancing pre-service teachers’ understanding of problem solving in classical mechanics; a topic that most of them found difficult because it required a strong mathematical ability. A related issue was to deploy DAIM as a means to create the needed intellectual space to cover the conceptual gaps for those grappling with conceptual resources (CR) i.e. knowledge of classification, terminology, principles, theories, models, structures, algorithms, and strategies needed to solve problems in science. In other words, DAIM was mobilized to obviate the need to spend a lot of time doing basic remedial mathematics in class.

Several studies have examined the common difficulties that learners and teachers tended to encounter when dealing with mathematically demanding problem solving in school science (e.g., Bason & Kriek, 2012; Kuo, Hull, Gupta, & Elby, 2013). A lot of studies have shown argumentation as
an effective instructional for solving all kinds of problems in science (e.g. Jonassen, 2011; Simon & Johnson, 2008). For this reason, we adopted DAIM, as espoused by Ogunniyi (2009), to provide the needed discursive communal learning environment where participants communicated their viewpoints with their peers as well as reflected on their own assumptions and came up with new ideas on how to solve given problems in classical mechanics.

DAIM as an instructional strategy is underpinned by the Contiguity Argumentation Theory (Ogunniyi, 2007a). CAT recognizes five dynamic cognitive states that an individual could adopt in an argumentation context while trying to solve a problem. They are: Dominant-the most prevalent worldview being mobilized to solve the problem in a given context; Suppressed-the worldview subdued by the more dominant one; Assimilated-the worldview that is subsumed by the more dominant one; Emergent- the worldview that evolves from a new experience e.g. the acquisition of a new concept in a science class; Equipollent-two powerful worldviews exerting equal cognitive force on a person’s worldview. Each of these cognitive states can change from one form to another depending on the arousal contextual stimulus in vogue (Ogunniyi, 2007a).

**Purpose of the study**

The aim of this study was to examine the challenges that pre-service teachers face in developing conceptual resources needed to solve science problems in classical mechanics.

**Methodology**

Two comparable physics education classes designated S1 (E group) and S2 (C group) were exposed to two hours of instruction on problem solving in physics twice a week for six months. E-group was exposed by the first author to DAIM while the C-group was taught by another lecturer using the traditional lecture method. The learning and teaching process was evaluated in terms of (1) the magnitude of changes observed by data collected and (2) the number of pre-service teachers who had changed on the variables measured based on their performance on 12 tasks covered by PSAT. In all, data were generated from the PSAT, semi-structured interview and field notes.

**Results**

Results in Table 1 showed that E-group had higher mean scores than their counterpart C-group. We observed at pre-test \((F_2, 38 =0.297 =4.098 @ p=0.05\) and at post-test \((F_2, 38 =3.338 =4.098 =@ p =0.05\). We found no significant difference in scores of the E-group versus the C-group on tests observed.
Table 1 Analysis of pre-posttests scores for E and C groups

<table>
<thead>
<tr>
<th>Sources (N= 40)</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups-BG</td>
<td>24.025</td>
<td>1</td>
<td>24.025</td>
<td>0.297*</td>
</tr>
<tr>
<td>Within Groups -WG</td>
<td>3077.95</td>
<td>38</td>
<td>80.998</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3101.975</td>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post-test</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups-BG</td>
<td>207.025</td>
<td>1</td>
<td>207.025</td>
<td>3.338*</td>
</tr>
<tr>
<td>Within Groups -WG</td>
<td>2356.75</td>
<td>38</td>
<td>62.019</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2563.775</td>
<td>39</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sources</th>
<th>M</th>
<th>SD</th>
<th>Variance</th>
<th>Omega Sq</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-Group (Pretest):</td>
<td>(35.3)</td>
<td>(9.48) [9.76]</td>
<td>(85.4)</td>
<td>.58 (58%) *</td>
</tr>
<tr>
<td>[Posttest]</td>
<td>[42.85]</td>
<td>[90.52]</td>
<td>[68.5]</td>
<td></td>
</tr>
<tr>
<td>C-Group (Pretest):</td>
<td>(33.8) [38.3]</td>
<td>(8.5) [5.36]</td>
<td>(68.5)</td>
<td></td>
</tr>
<tr>
<td>[Posttest]</td>
<td>[27.31]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: F-critical = 4.098* at 0.05 level*).

A further analysis of omega square was carried out to note which of the groups benefitted more from the two instructional approaches in problem-solving. Omega square of 0.58 was moderate showing that the observed difference in the variance scores of the two groups was due to the treatment method of instruction adopted for teaching problem-solving.

Table 2 Distribution of pre-service teachers’ categories of CR gauged by the CAT

<table>
<thead>
<tr>
<th>Stage of Dialogical argumentation CAT</th>
<th>Positive attributes (N)</th>
<th>Negative attributes (N)</th>
<th>Positive attributes (%)</th>
<th>Negative attributes (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dominant: Stage 1</td>
<td>36</td>
<td>42</td>
<td>54</td>
<td>46</td>
</tr>
<tr>
<td>Suppressed: Stage 2</td>
<td>29</td>
<td>–</td>
<td>48</td>
<td>–</td>
</tr>
<tr>
<td>Assimilated: Stage 3</td>
<td>38</td>
<td>–</td>
<td>52</td>
<td>–</td>
</tr>
<tr>
<td>Emergent: Stage 4</td>
<td>22</td>
<td>–</td>
<td>36</td>
<td>–</td>
</tr>
<tr>
<td>Equipollent: Stage 5</td>
<td>13</td>
<td>–</td>
<td>22.5</td>
<td>–</td>
</tr>
</tbody>
</table>

From results in Table 2, it emerges that pre-service teachers conceptual resources (CR) with emphasis on scientific knowledge was dominant at CAT stage 1 (54%). Notions held by pre-service teachers were suppressed at 48% CAT stage 2. As more rebuttals ensue in communal activities of the PSAT, ideas held by the pre-service teachers were assimilated at 52%, CAT stage 3, emergent by 36% and equipollent by 22.5% in small group discussions. Retaining of notions for correct conceptual resources needed to solve physics problems at posttest stood at 58% suggesting a cognitive shift for the E-group, and 37% for the C-group. We found a statistically important relation between the levels of pre-service teachers’ dialogic argumentation and their performances on the 12 PSAT items to be ($\chi^2 = 12.67$ df = 2 $p < .001$, not shown in the table). This relation may be attributed to the instruction tool (DAIM).
Further, qualitative data indicated difference in the way both E and C groups responded to the PSAT activities. For example, PT18 (E-group) elaborated on the confidence and ease members of her group gained during problem-solving, while her counterpart, PT23 (C-group) corroborated his views on PSAT items being difficult to solve. Lack of space would not permit other participants’ stances similar to those above.

Discussion and conclusion
The results of this study showed that only seventeen of the 40 pre-service teachers were able to solve 7 out of the 12 PSAT items successfully at pretest. A within subjects’ analysis of the dataset showed that more than 65 percent of the pre-service teachers limited initial problem statement, failed to check pertinent variables that impinged on the problem, formulated solution without exploring alternatives. At posttest, significant gains in overcoming the challenges they faced in developing conceptual resources (CR) needed to solve physics problems were observed, e.g. E-group (62%) and C-group (41.2%) solved the 12 PSAT activities correctly, implying an improvement on their CR.

From the findings of this study, it seems that equipping the subjects with problem-solving skills using DAIM might have enhanced their ability to overcome some of the challenges they faced in developing conceptual resources needed to perform the assigned tasks in classical mechanics. The findings are likely to provide additional insights to studies concerned with facilitating problem-solving skills among science teachers and their learners (e.g., Bason & Kriek, 2012; Kuo et al., 2013), and in using argumentation instructional model (Ghebru & Ogunniyi, 2017).

References


THE EFFECT OF COMPUTER SIMULATION-BASED INSTRUCTION ON PERFORMANCE IN CHEMICAL REACTION RATE OF GRADE 12 LEARNERS IN SEKGOSESE EAST CIRCUIT

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Abstract

Chemical Reaction Rate (CRR) is one of the topics which grade 12 Physical Science learners are finding challenging. The need to find better strategies for teaching this topic to improve learners’ performance led to this study to investigate the effect of Computer Simulation-Based Instruction (CSBI) on learners’ performance in CRR. The study employs a pre-test/post-test non-equivalent control group quasi-experimental design. Cognitive theories of learning constitute the theoretical framework guiding the study. These theories are Cognitive Theory of Multimedia Learning (CTML) and Cognitive Load Theory (CLT). The sample consists of learners in two classes; one of which will serve as experimental and the other a control, in two secondary schools located in Limpopo Province. The experimental group will be taught using CSBI and the control group using the traditional approach. The null hypothesis tested is: There is no significant difference in performance of learners taught using CSBI and traditional approach. Data will be collected using pre-test and post-test. In data analysis, the independent t-test will be used to find out if the experimental group will perform better than the control group. The findings are expected to inform Chemistry educators, subject advisors and curriculum developers on how to improve learning in CRR.

Key concepts: Computer Simulation-Based Instruction, Learner-Centred Approach, Chemical Reaction Rate.

Introduction

CRR is a topic in the chemistry section of Physical Science. It is considered an anchoring concept in chemistry (Bain & Towns, 2016:246). CRR enables understanding of chemical processes in industrial, medical, pharmaceutical and environmental fields (Justi, 2003:293). An understanding of CRR is therefore important for further learning in Chemistry and related future careers.

CRR is considered a difficult concept in chemistry both by learners and teachers (Chairam et al., 2015:937). It consists of abstract and complex concepts. Grade 12 Physical Science Paper 2 final examination question on CRR was analysed by expressing the average marks obtained as a percentage of the total marks on the question. The results from 2012 to 2017 are shown in Fig. 1 below. Learners persistently underperform in CRR.
Many Physical Science teachers in South Africa have limited content knowledge, use ineffective teaching approaches, and rely mostly on traditional methods (Kriek & Grayson, 2009:185). Over-reliance on ineffective teaching approaches may contribute to poor learners’ performance in CRR. Hence, this study explores the prospects of chemistry simulations in aiding learners’ understanding of CRR concepts.

**Literature Review**

Chemistry simulations are dynamic visualisations of chemical phenomena (Suits, 2015:611). They enable learners to explore relationships among variables in models simulating CRR (Kulik et al., 1980:529). Learners manipulate the variables of a chemical system and then run the simulation in order to observe its outcome on the dependent variable (Suits, 2015:611). Therefore, these simulations are interactive.

Computer simulations enable learners to observe details of chemical reactions that are too hazardous, expensive or time-consuming for laboratory work (Justi, 2003:310). Simulations also provide visualizations of phenomena that are impossible to see in the real world (Ainsworth, 2008:193). They provide abstract explanations as they enable three dimensional and dynamic representations of chemical phenomena (Justi, 2003:310).

The debate in chemistry education is on how and when simulations can be used effectively (Goedhart, 2015:76). To achieve active learning, the present study makes use of the Predict-Observe-Explain (Bajar-Sales et al., 2015:6) strategy in CSBI.

**Methodology**

The present study, informed by the post-positivist paradigm (Guba & Lincoln, 1994:110), is a quantitative research seeking to find cause-and-effect relationships. It uses a quasi-experimental methodology where a Non-equivalent Control Group Design with pre-test and post-test is adopted (Cohen et al., 2007:283). The independent variables are the method of instruction. The dependent
variables are learners’ performance as measured by scores obtained from Test on Chemical Reaction Rate Concepts. Data collection will use pre-test, teaching of the experimental and control groups, followed by a post-test.

Way Forward

Since simulations enable learners to visualize chemical reactions at the particulate level, they have great potential in improving learners’ conceptual understanding in CRR. Hence, this study attempts to find how effective they are compared to current practices.

References


TEACHERS’ CONCERNS WITH THE IMPLEMENTATION OF PRACTICAL WORK IN THE PHYSICAL SCIENCES CURRICULUM AND ASSESSMENT POLICY STATEMENT

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Abstract

In 2012, a Curriculum and Assessment Policy Statement (CAPS), was introduced in South Africa. The emphasis was learner-centred and constructivist approaches to practical work in the high school subject physical sciences. These demands for practical work and inquiry skills would be a tall order for most teachers under the best of circumstances. The South African context, with limited resources, such as laboratories and supplies, adds a further complication to the implementation challenge. The purpose of this study was to evaluate teachers’ concerns and experiences with the implementation of practical work in physical sciences. A quantitative study involving a survey of 81 randomly sampled grades 10, 11 and 12 physical sciences teachers in one of the school districts in South Africa was conducted as part of a larger investigation. The concerns-based adoption model (CBAM) was used to identify teachers’ stages of concern (SoC) of the practical component of CAPS. The findings indicate that nearly 60% of the teachers (n=47) in the study had management concerns of high significance (p=0.51) while the collaboration and consequence concerns were only slightly significant (p=0.96). This means that teachers are rather perturbed about organising and coordinating the activities required for conducting and supervising practical work in order to achieve the CAPS requirements. There is also limited participatory decision-making and sharing of visions among physical sciences teachers. The paper concludes with a discussion on the variety of concerns and how these might be addressed through professional development and more targeted teacher support.

Keywords: teachers’ concerns, practical work, physical sciences, concerns-based adoption model
HISTORICAL EXPERIMENTS AS TOOL TO ENHANCE LEARNING OF CONCEPTS AND ELECTROSTATICS PHENOMENA: A Case Study of Grade 11th Learners in Mozambique

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The world around us is in constant changes, implying a change in the educational paradigm that is geared towards the development of competences. These competences are linked to the knowledge of the nature of science, scientific literacy and scientific argumentation including the knowledge about technology. Recognizing the role of history and philosophy of science in teaching, defended by Ernest Machin1887, Michael R Matthews in 1989, Pierre Duheimin1906 and John Dewey in 1920 many researchers in Physics Education have chosen this method to make teaching science more graceful, which is a consensus option. The practice has shown that the experimental component is being neglected, although it is implicitly linked to history and philosophy of science. The purpose of this study is to describe the learning environment of electrostatics in grade 11 in the traditional way. Later is also analyzed the students learning through the integration of electrostatic historical experiments as a didactical tool in the classroom. Other objective of this research is to evaluate through the historical view, the potential of developing new perspectives of teaching and learning physics in Mozambique. The reason of selecting electrostatic is because the contents taught are merely abstract and they play a role to the explanation of electrodynamics concepts such as electrical current, voltage, concepts and laws related to generation, transport, conservation and distribution of electricity. The concepts of electrostatic and electrodynamics are all related to the operation principle of different electrical appliances and also the foundation of technology. The experience shows that when learners are asked to show their creativity in terms of building Physics experiments, they tend to electricity among other fields of Physics in the secondary school such as Matter structure, Mechanic (Kinematic, Dynamic and Static), Work and Energy, Thermal phenomena, Solid and Fluid Statics, Geometrical Optics, Electricity and Magnetism, Electromagnetic Waves, Black Board Radiation, Atomic Physics, Nuclear Physics, Fluid Mechanic, Hydrodynamic, Gas and Thermodynamic, Oscillations and Mechanic Waves. So in this research is considered that the learner’s enjoyment is to understand the concepts of electricity which starts from the knowledge of electrostatics, the main focus of this study. Whereas, physics is an empirical science, where the observation and experimentation play a crucial role in the treatment of contents. Therefore, the goal of this research is to analyses the effect of historical devices of electrostatics in learning electrostatic concepts and phenomena, including building the nature of science and improve academic literacy to grade 11th learners in Mozambique. Historical devices were built by the scientists in the past and played an important role for design, development of theories, concepts, and laws actually accepted, (Paula & Laranjeira, 2006). In this research, Historical experiments are applied to teach the electrostatics concepts such as electric charge and its
proprieties; electric field and its proprieties, electrical potential to grade 11 learners. Is important to refer that this approaches is also emphasized in the Physics teaching program of Mozambique when it considers that with the inclusion of some elements of historical focus in the programs, it is intended, in particular, that students know aspects of the life, work, activity and points of view of eminent scientists and develop appropriate moral values (MEC &INDE, 2010, p.7). These concepts are raised from the historical view through the use of electrostatics experiments, worksheets, posters and short historical videos about electrostatics. When the learners are passive in the learning process, then the learning is called traditional. In this process the learners do not build their own understanding of science. The teacher’s activities are based on delivering the content by exposing in the board or by dictating. The most prevalent VAK, teaching style in the traditional methodology is auditory. The common didactical resources used in the traditional style are based on chalk, black board, rulers, test books, exercises books and exercise sheets for students. Sometimes it is possible to find some experimental materials for demonstration where students observe and try to describe phenomena, but they do not use worksheets. In addition, the common activities of students in the class are related to write notes and solve exercises based on data replacement. Through these elements is possible to say that there is rote or mechanic learning of Physics contents. To integrate this approach in the classroom will be applied the theoretical framework of Model of Education Reconstruction (MER) (Duit, et al, 2012) and the Cognitive- Historical Reconstruction (CHR), (Nersessian, 1992). MER is composed by three core elements:

(1) Design and evaluation of teaching and learning environment in this case about electrostatics,
(2) Research on teaching & learning
(3) Clarification and analyses of science contents.

Nevertheless, CHR is also composed by two core elements such as

(1) contemporary model related to conceptual structure and
(2) historical model relates to cognitive process.

To fulfil the application of this model a course of 13 lessons is designed where material is provided by the research. Two schools in the rural area of Sofala Province were selected as the population and sample of (N=400). The selected sample is divided in control and experimental group and the methodology of Pre-test, intervention and post-test is applied. The Pre-is divided into 2 parts, the first is motivation test of 25 questions SMQ II of reliability $\alpha = 0.92$ (Glynn et al, 2011) measuring 5 factor analyses elements (intrinsic motivation, career motivation, self-determination, self- efficacy and grade motivation). The second part is learning outcome test, measuring the common misconceptions of the students about electrostatics. The results of these step allow to the researcher to design materials and lesson plans for intervention. In this pre-test and post test period both groups control and experimental group is assessed in the same way. The only difference will be in the intervention, where the experimental group the 13 lessons course will be designed while for the control group the activities will be the chalk based and all normal activities of the lessons. For this,
the sample will be randomized to create an experimental group (200) and control group (200), assisted by two teachers T1 and T2. Semi-structured interview for Physics teachers took place to diagnose their PCK regarded to electrostatics contents. The first step of this research is the validation of the instruments learning outcomes test and guide of interview for Physics teachers. The results to be presented in this conference are regarded to analyses the level of motivation of the students through the traditional methodology, the learning outcomes of the students after learning electrostatics in the traditional methodology, also the PCK of the teachers in electrostatics contents. The experiments to be integrated are based on Assis (2010), Bassalo (1996), Buchwald & Fox (2014), Heilbron (1979), Guedes (2000) and Guedes (2003) who described the history of electrostatics in five periods. Also plays crucial role in this research the ideas of reconstructing historical experiments according to Russel (1981), Conant (1951); Chang (2011), Heering (2009), Boss (2011) and Höttinge et al (2010). The data of the questionnaire are categorized and analyzed by SPSS 21.0 program inferring complex linear modeling through, T Test, analysis of moment structures (AMOS) and WILCOXON. These results are strongly considered in preparation of lessons plans, learning materials and environment of the classes. The PCK is assessed here to see the reason of some learner’s misconceptions. While the learning outcome instrument is used in the reflection of which aspects to considerer when planning the activities for intervention second stage.

Keywords: model of didactic reconstruction, historical experiments, replication method, learning concepts, motivation, electrostatics learning outcomes.

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THE NATURE OF THRESHOLD CONCEPTS OF ARRHENIUS, BRONSTED-LOWRY AND LEWIS ACIDS-BASES IN FRESHMEN’S CHEMISTRY

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Abstract
The paper describes the nature of threshold concepts (TCs) as a learning tool to teach and learn acids-bases introductory chemistry by first-year university students. The idea considered is based on the challenge’s students face in general chemistry which discourages them from studying chemistry, pursuing their studies in chemistry-linked professions, such as, medicine, engineering, agriculture, natural resources and chemistry education or dropping out of the university completely. In my institution, all freshmen studying natural sciences, engineering, and mathematics and science education have general chemistry as a prerequisite. Over the past many years, the university experienced low pass rates amongst first-year chemistry students with a large number failing chemistry and proceeding to second-year repeating first-year chemistry and some eventually dropping out (2010-2016, the board of studies report). The acids-bases chemistry has been identified by chemistry scholars as one of the threshold concepts in chemistry (Furio-Mas, Calatayud, & Guiaselo Furio-Gomez, 2012) that seems to be the culprit. Acids-bases are also cardinal to learning of other chemical reactions within the discipline and other science concepts in life sciences (biology) and physics (Cooper, Kouyoumdjian & Underwood, 2016). This makes acids-bases concepts as one of the basic chemistry concepts that are taught in primary school, secondary school and university levels (Kala, Yaman & Ayas, 2012). To address this problem, we looked at the nature of TCs theory and apply it to acids-bases, teaching and learning.

Keywords: Threshold Concepts, Arrhenius, Bronstead-Lowry and Lewis, Dropout Rates, Teaching and Learning
Historically, researchers and theorists associate science education with civic, economic, and industrial progress (Quinn et al., 2012; Turner, 2008; Villanueva, 2010). However, science achievement in the United States lags behind other developed nations (Fleischman, Hopstock, Pelczar, & Shelley, 2010). Though National Assessment of Educational Progress (NAEP) science assessment data shows steady yet significant increases in scientific achievement over the past 25 years, on the 2015 assessment only 41% of 4th grade students and 37% of 8th grade students in America met proficiency standards (National Center for Education Statistics [NCES], 2015). Made worse, students with disabilities continue to score significantly lower than peers without IEPs; only 18% of 4th graders with disabilities and 11% of 8th graders with disabilities met proficiency standards in 2015 (NCES, 2015). English Learners (ELs) performed worst of all, with under 5% of students in 4th or 8th grades attaining a score of proficient or above. Based on trajectories from the last quarter century, these gaps are persistent. Without focused and empirically-validated interventions, the gap is unlikely to be closed. It is clear that improvement at scale, beginning with experimental tests of new instructional approaches in individual schools and classrooms, is needed.

Problem with Vocabulary Instruction for Inclusive Middle School Science Teachers

One big issue for teachers and students is the amount of content packed into each science course (Kesidou & Roseman, 2002). For example, Virginia middle school students pass through a sequence of science courses in grades 6, 7, and 8; each has over 100 new vocabulary terms and concepts. Many of the terms are specialized, in that they have no direct meaning outside of their use in science, therefore making it unlikely students will bring any background knowledge to help learn the term. Examples include meiosis, cytoplasm, and exothermic reactions. In addition, many terms, like meiosis, are accompanied by a series of related terms needed to fully understand the concept (e.g., prophase, metaphase, anaphase, telophase, and that’s just meiosis stage 1). This constitutes a major cognitive lift for students with disabilities given the volume, complexity, and seemingly arbitrary nature of many terms/concepts in science. In sum, even if instruction is “perfect,” students with disabilities may still not be successful.

A problem noted in Virginia, but occurs all over.

Virginia only assesses students statewide following the 8th grade with a cumulative assessment covering standards from all three grades. The 8th grade science assessment therefore includes over 300 unique vocabulary terms and concepts, which must be memorized, and applied in response to
various questions of science proficiency. The sheer number of terms forces teachers’ hands in terms of how they structure their classes, and how students are prepared for the 8th grade assessment prior to moving on to high school and college (Yore, Hand, & Florence, 2004). Therefore, teachers are compelled to take a sizable amount of time to teach vocabulary terms and concepts, but their methods are usually structured for efficiency of class time, and not optimized to meet students’ learning needs (Schmidt, Wang, & McKnight, 2005). In other words, teachers have students copy definitions from lecture using the board or PowerPoint slides with little to no discussion or deep exploration of term meaning. In Virginia, this problem of practice has taken a toll. The statewide pass rate for students with disabilities on the 8th grade assessment was 40.4% in 2014-15, 42.0% in 2015-16, and 43.6% in 2016-17. The pass rate for ELs was 45.0% in 2014-15, 44.0% in 2015-16, and 53.6% in 2016-17. The statewide pass rate for all students in those same years (excluding students with IEPs and ELs) was 84.3, 85.7, and 86.0, respectively. Hence, the disparities evident at the national level are consistent with these specific issues found in Virginia.

Why are outcomes so poor?
Project PI Michael Kennedy completed perhaps the largest ever examination of how inclusive middle school science teachers spend their time across the past three years (2015-18) as part of his IES-funded early career project. In total, 70 inclusive middle school teachers and almost 5,000 students participated in these studies. Researchers completed 475 unique observations for over 26,000 minutes (not including lessons double scored for reliability and training purposes). Observations were conducted on instructional days. Half of the observations were under baseline conditions; in other words, we were watching teachers’ business-as-usual approach to vocabulary instruction. With exceptions, the inclusive science teachers we observed over the past three years do not implement evidence-based vocabulary practices with the regularity or intensity needed to support the learning needs of students with disabilities. Teachers were often observed providing dictionary definitions for terms (text only), which students copied from an overhead projector/CPU without elaboration or discussion, and/or having students create low-level study guides (consuming an average of 30-45 minutes per lesson). The Next Generation Science Standards (NGSS) call for science classrooms to integrate scientific practices, disciplinary core ideas, and crosscutting concepts in a three-dimensional approach (NGSS Lead States, 2013). However, in our 475 observations, we noted fewer than 10 lessons that engaged students in scientific practices (and three of the lessons were from the same teacher). While we can only speculate as to the reason(s) why, what we do know is most inclusive middle school science teachers need support to improve their instructional practice for all students, and especially students with disabilities and ELs. Our multimedia PD process is scalable, and customizable to suit teachers’ content area needs.

The RCT (described in more detail below) provided inclusive middle school science teachers with vocabulary supports with the aim of boosting achievement for students with and without disabilities. We targeted specific evidence-based practices for teaching vocabulary, including providing student-friendly definitions, using examples and non-examples, breaking terms into morphological parts,
highlighting semantic relationships among related terms, and having discussions. We situated these practices within traditional science instructional pedagogies to facilitate buy-in from teachers. The three components of our PD process (vignettes including modeling videos, curriculum-linked, customizable teaching materials, and coaching) result in improved teacher practice by building teachers declarative, situated, and procedural knowledge (Alexander, Schallert, & Hale, 1991). Our modeling vignettes provide direct instruction on the steps of each practice, and then show a teacher modeling the practice (see https://vimeo.com/143387419). Next, teachers receive access to curriculum materials in the form of customizable slides that use the practices taught within the vignettes (see www.vocabsupport.com). Finally, teachers are observed by a researcher (or colleague) using the Classroom Teaching (CT) Scan, which is a low-inference, real time observation tool that generates descriptive data to be used in coaching (see: http://www.classroomteachingscan.com/ctscan/timeline.htm?menus.txt&474). The coach uses these descriptive data to generate a written report free of opinions/biases, and instead focuses on how teachers are spending their time, and areas for improvement. The coaching then links back to the multimedia vignettes and implementation of slides.

Our PD process is intended to support teachers with limited knowledge and readiness to support the needs of students with disabilities. Students from rural and urban areas are often taught by teachers with limited knowledge/training. Therefore, we argue that members of traditionally marginalized groups will be in good position to benefit from our work. In addition, our materials are free, and can be accessed using the links above.

Evidence
Study one.
In study one (2015-16), researchers used a multiple baseline design to evaluate the impact of the multimedia PD process on the vocabulary performance of three inclusive middle school science teachers (see Kennedy, Rodgers, et al., 2017). The CT Scan was used as the dependent measure during 85 hour long observations. Results showed teachers made important and significant gains in the number of evidence-based vocabulary practices used in each lesson from baseline to treatment. Teachers went from an average of less than one practice used with fidelity per lesson at baseline to an average of 4.7 practices per lesson during treatment, and sustained that level of implementation five months later. Based on visual analysis, there was a level and trend change from baseline to intervention for all three teachers. The Tau effect size was .87, with a 95% CI of .54 to 1.21 (z = 5.166, p < .001), indicating a strong effect.

In addition to the improved number of quality teaching practices, each teacher significantly increased the amount of vocabulary instruction from baseline to post-intervention (average of 10% of lesson to average of 46% per lesson), and sustained average implementation to 40% of lessons when measured five month later without additional treatment (Kennedy, Rodgers, et al., 2017). Based on visual analysis, there was a level and trend change from baseline to intervention for all three teachers. The Tau effect size was .95 with a 95% confidence interval of .62 to 1.28 (z = 5.601, p <
.001), indicating a strong effect. Social validity data suggested teachers enjoyed the process, and iterative recommendations for improving the process were adopted.

**Study two.**
In study two (2016-17), Kennedy and his team recruited and randomly assigned 28 inclusive science teachers from rural schools to either receive the full PD process, or only access the CAP-TS materials (see Kennedy, Rodgers, et al., 2018). The teachers had 1,779 students, including 251 with an IEP who participated in the study. Each teacher was observed six times, three at baseline, three after accessing the PD/curriculum materials. The three baseline observations occurred within the first month of the school year. The three post observations were spaced to be approximately once per month and completed by January. Observers were blind to which condition teachers were assigned to, and used the CT Scan as the dependent measure of teacher practice. A research assistant (RA) who did not conduct observations had the only list of teachers’ group assignment. Thus, after each observation, the coaching email was sent to this RA, who then forwarded, or withheld the email depending on group assignment. All comparison group teachers received their emails after the conclusion of the study.

Unlike study one, where researchers used descriptive data to explain teacher growth, in study two a quality score for each lesson was generated using descriptive data provided by the CT Scan. The formula for the Quality Vocabulary Index (QVI) is: 

\[ QVI = \sum ((x+1) \frac{y}{z})_{ij} \]

where \( x \) is the percent of implementation markers (fidelity) used for a given practice, \( y \) is the duration (seconds) that the teacher used that practice, and \( z \) is the duration (seconds) of the entire lesson. The percent of IMs for each practice \( x \) is added to 1 because if a teacher uses a practice without any IMs it would be as if they never used the practice, and we argued using a practice without full fidelity was better than not using it at all. Each teacher received a QVI score for each of the six observations. Researchers conducted 76 baseline and 80 post-intervention observations for a total of 8,767 minutes. There were no significant differences in mean QVI between teachers in the two experimental groups at baseline. Teachers in the full multimedia PD group had an average QVI for the three post observations of .9035 (SD = .377), and peers in the curriculum materials only group had an average QVI of .5117 (SD = .465). The difference was statistically significant \( F(1, 78) = 17.2, p < .001, d = .93 \).

Students completed two measures, one distal, one proximal. The first is a standardized, NSF-funded measure of overall science performance called the Misconceptions-Oriented Standards-Based Assessment Resources for Teachers (MOSART). Students also completed three curriculum-based measures of science vocabulary knowledge (monthly, tied to teacher observations) created using procedures detailed by Espin, Shin, & Busch (2005), and others.

Analyses were conducted through Mplus using the complex procedure to control for the nesting of students in classrooms. All impact analyses gave consideration to inclusion of the student level covariates of grade level, gender, race (White vs. non-White), SES, IEP status, and average teacher
QVI score for the three observations post-intervention. Evaluation of the impacts on science outcomes was based on a pre- and posttest of science knowledge (MOSART). All models were initially estimated with inclusion of the aforementioned covariates. Thereafter, covariates with the largest p-value greater than .20 were dropped from subsequent models (Price et al., 2007). This was repeated until only control variables meeting the < .20 threshold remained in the model. Exceptions to these exclusion rules were applied to pretest MOSART score and the average QVI for the three post-observations. These variables were retained in all model evaluations. There were no significant differences between students in the two experimental groups on the MOSART at baseline.

Students exposed to teachers from the CAP-PD group (N = 876) scored an average of 2.4 points higher on the MOSART at posttest than students exposed to teachers who only accessed the CAP-TS materials (N = 781); b = 2.37, p = .005, after controlling for meaningful covariates. Students exposed to full multimedia PD teachers scored an average of 1.01 points higher on the first CBM than students with comparison group teachers; b = 1.01, p = .06, after controlling for meaningful covariates. The same was true for students with teachers from the multimedia PD group for CBM 2 (1.3 points higher; b = 1.26, p = .04) and CBM 3 (1.51 points higher; b = 1.51, p < .001), after controlling for meaningful covariates.

Students with IEPs with teachers from the multimedia PD group (N = 132) scored an average of 1.4 points higher on the posttest science scores than students with IEPs from teachers in the comparison group (N = 108). However, this difference was not statistically significant; b = 1.37, p = .28, after controlling for meaningful covariates. Students with IEPs with teachers from the multimedia PD group scored an average of 0.32 points higher on the first CBM probe than peers with IEPs with teachers from the comparison condition. However, this difference was not statistically significant; b = 0.32, p = .56, after controlling for meaningful covariates. The same was true on CBM 2, (1.02 points higher; b = 1.02, p = .14). However, students with IEPs with teachers in the multimedia PD group did significantly outperform peers with IEPs on the final CBM probe (1.45 points higher; b = 1.45, p < .02), after controlling for meaningful covariates. If the study had continued, it is possible that these observed gains would have continued, and possibly expanded. We address that question in this project. The patterns of all results demonstrate a moderator relationship as there was a significant interaction between group membership and time on the MOSART and CBM measures.

**Study 3.**

In 2017-18, Kennedy and colleagues randomly assigned 39 teachers to either receive the multimedia PD process, or be in a wait-list control group (business-as-usual, BAU). Approximately 3,200 students participated in this study. Researchers continued using the CT Scan to observe teachers three times at baseline and three times after accessing study materials. In addition, the CLASS-Secondary measure (Pianta, Hamre, Hayes, Mintz, & LaParo, 2008) was added as a dependent measure of teacher quality, and used once at baseline, and again in the final observation post intervention. The
same blinding procedure for observers noted above was utilized again for this study. Data collection was recently completed for this study (mid-February, 2018). Thus, student data are not yet available.

Teachers in the multimedia PD group (N = 20) had a higher average QVI score for the three post-intervention observations (M = .875, SD = .349) than colleagues in the BAU group (N = 19, M = .195, SD = .131; d = 2.55. This effect size is larger than our finding from study 2, which is logical given that the comparison group in study 2 had access to the curriculum materials, and the control group teachers in this study did not. The CLASS-Secondary measure provides a quality score for each of 12 dimensions. This measure was added to provide a distal measure of teacher quality, and to add a dependent variable not so closely tied to the intervention. Results were not significantly different for any of the 12 dimensions between the groups for the first observation pre-intervention. At the post-observation, teachers in the multimedia PD group had higher scores for the following dimensions: Teacher Sensitivity, F(1, 37) = 7.0, p = .012; Productivity, F(1, 37) = 6.0, p = .019; Instructional Learning Formats, F(1, 37) = 14.3, p < .001; Quality of Feedback, F(1, 37) = 9.3, p = .004; Instructional Dialog, F(1, 37) = 5.8, p = .021; Student Engagement, F(1, 37) = 7.1, p = .012. All others were not statistically significant although it is worth noting the multimedia PD group had a higher mean score for each dimension other than Negative Climate (the one dimension in which a higher score is undesirable).

PARTICIPANT OUTCOMES:


2. Participants will understand the rationale for first building teachers' knowledge of evidence-based practices, and then providing curriculum-linked scaffolds for lasting implementation and effectiveness.

3. Participants will receive knowledge about data-driven coaching, the type made possible by the Classroom Teaching Scan. We will describe the Quality Vocabulary Index (QVI), which is the main dependent variable for teacher quality. The QVI is expressed as QVI = \( \text{SUM}(x+1)y/z \) where \( x \) is the percent of implementation markers used for a given practice (fidelity), \( y \) is the duration the practice was used for, and \( z \) is the duration of the entire lesson. We are therefore using descriptive data to generate a quality score that can be interpreted. The QVI correlates with student outcomes as noted in our description.
REFLECTING ON THE PREPARATION OF POWERPOINT SLIDES AS A RESOURCE IN BIOLOGY LECTURES
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Abstract
In this study, I was interested in understanding how my experiences influenced my preparation of PowerPoint slides to teach biology to pre-service teachers. To achieve this, I used a self-study. The primary source of data was my reflective journal and the PowerPoint slides. With the help of critical friends, I gained insights about not only preparing PowerPoint slides but also incorporating worksheets in the PowerPoint slides. A recommendation from the study is that practitioners can reflect on the practice and use those experiences as tools to inform effective teaching.

Introduction
Instructional materials refer to any artefacts; either visual, audio or concrete that are used in the classroom by the teacher and/or students for the purposes of learning (Awolaju, 2016). In higher education, a PowerPoint presentation is the predominantly used instructional material (Roblyer & Doering, 2013). Authors who find the ineffectiveness of PowerPoint point the design and order of the slides as a contributing factor (e.g. Brock, Jonglekar & Cohen, 2011). Biology is populated with diagrams and structures an understanding of the ‘structure’ is a pre-requisite to learning the functions and processes. As such, the PowerPoint becomes beneficial in showing pictures of the biological structures. In my undergraduate studies, I attended lectures where slides were populated with texts next to these pictures. This led to the domination of lecturer talking and little engagement with the students. In this study, I am narrating how my experiences and reflections inform my preparation of instructional materials. I do this to answer the research question: How does my reflection on using instructional materials inform my preparation to teach biology to pre-service teachers?

Instructional materials as tools for transforming the subject matter knowledge
Shulman (1987) introduced the concept of Pedagogical Content Knowledge (PCK) as a special kind of knowledge that teachers need to have in order to teach effectively. PCK is about the transformation of the content knowledge in ways that make the content accessible to students. In the process of transformation as depicted in Shulman’s (1987) model of pedagogical reasoning and action, the teacher needs to think about selecting powerful instructional materials. The use of slides in PowerPoint is one of the materials that can be used to enhance learning. One of the aspects of
transformation in this model is adaptation of those instructional materials and representations used (Starkey, 2010). In this context, adaptation is about the design and tailoring of the PowerPoint slides to suit teaching biology to pre-service teachers.

**Research design and methodology**

Using a self-study methodology, I studied my ideas and actions (Samaras, 2011). I used narratives as an approach to articulate my experiences that influence my preparation of PowerPoint slides as an instructional material.

**Participants and context**

I was the main participant as a novice biology teacher educator. I am learning to teach biology to pre-service teachers at a South African university. I prepared the slides to teach 135 third year biology pre-service teachers. I prepared the slides to teach the human ear (one week) and population ecology (3 weeks) in March 2017 and September 2017 respectively.

**Data collection and analysis**

I kept a reflective journal where I was continually recording my thoughts on how to prepare effective PowerPoint slides. After preparation of seven months, I presented the slides and the reflections to my five critical friends for the comments. I used their feedback to further reflect and gain insights of my practice.

**Reflecting on my undergraduate experiences**

My undergraduate Biology lecturers, used PowerPoint slides extensively as a teaching resource. However, as a student I did not think the slides were influencing my learning. Many slides were overloaded with text placed next to a diagram. When preparing my lectures, I assumed that I needed to use PowerPoint slides as this was how I had experienced Biology lectures. My reflection is shown below.
The above reflection directed my thinking. After presenting the PowerPoint slides to my critical friends, I had a conversation with Nairobi:

**Nairobi:** What will you be doing with students when you display this slide? [The slide had the structure of the ear with explanations below]

**I:** I want to interact with them...sort of asking questions as explain the structure

**Nairobi:** I don’t know what you will ask them but the explanation at the bottom tells about the picture [13/03/2017]

**My response: thinking about my students**

Her question intrigued me because she said “with students”. This gave me a signal that in preparing the slides, I need to think of students and ask myself the question ‘what am I doing with each slide on my PowerPoint?’ Answers to the questions that I would ask were captured in the explanation at the bottom of the slide. I then decided to separate the ‘structure’ and text. This was an insight for me not to only show the structure of the human ear for hearing in one slide (A) but to allow the interaction as we talk about the relationship between structure and function of human ear.

Brock et al. (2011) assert that instructors need to ask themselves the question of whose benefit the slides are for. This is what directs the order of slides and amount of time invested in preparing these slides. So, what I gain from the authors and Nairobi about preparing PowerPoint slides is that I need to understand for whom the slides are prepared (students, lecturer or both) and the purpose (e.g. for students to copy the notes) I am preparing the slides for.

**Using slides to engage students – incorporating worksheets**

When I engaged with what I gained above and reflecting on teaching the human ear, I realised that a straightforward movement from slide A to B does not engage students in a way that I envisaged. After reading a paper by Sujarittham et al. (2016), I got an idea of incorporating worksheets. I define a worksheet as a print out with a set of questions and spaces for answers. I asked myself; how do I prepare these worksheets without discarding the PowerPoint slides? I also asked this question to my critical friends and Celia asked; “what do you want to do with worksheets?”
My answer to Celia’s question was that I want students to engage with content that we talk about using the slide with a diagram or a biological structure. I thought introducing the worksheet after slide would be beneficial as shown below.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
</table>
| ![Slide Diagram](image1.png) | ![Worksheet](image2.png) | **Random**  
Not common in nature.  
Uniform  
- Results from competition for resources.  
- Animals: territory  
- Plants: sunlight  
**Clumped**  
Most common in nature.  
Social interaction provides advantages. |

In this order of slides, I showed a diagram which serves as an aid for interaction about a concept of dispersion. To involve students more, I used the worksheet that has questions pertaining dispersion for students to put their thoughts down. The questions on the worksheet with instructions for example “think, write, pair and share” become part of the PowerPoint slides to serve as a signal to students. Slide C would not be available in the students’ hand-out because it would capture answers to B. Jane and Cecilia commented on my PowerPoint slides as follow:

**Jane:** You have many slides with good graphics and explanations...good thinking activities  
**Celia:** ...your slides, they look good, students can see pictures and engage...[5/04/2017]

*Jane’s last comment ‘good thinking activities’ and Celia’s comment ‘students can actually engage’ made me realise that structuring my slides in that manner is an indicator of my thinking about helping students to get access to the content moving from understanding the structure to understanding the function and process. In structuring the slides in that manner, I was trying to make sure that students can participate in my lectures by including more pictures/diagram and limiting text.*

**Conclusion**

In this study, I was interested in looking at how I can use my experiences to prepare instructional materials (PowerPoint slides and worksheets) as I transform the content knowledge. The process of critical reflection on my ideas and personal experiences helped me to ask myself questions and engage in self-inquiry about the purpose of PowerPoint slides in my biology lectures. A recommendation from the study is that teacher educators need to use their experiences and question their assumptions around these experiences for self-development and their practice of teaching pre-service teachers.
References


Abstract

In South African foundation phase science and technology education, few teachers have adopted science and technology process skills. Currently, science and technology education are encompassed in the integrated Foundation Phase Life Skills Curriculum and Assessment Policy Statement. We propose that this integrated curriculum lends itself to STEM teaching and learning. We describe a framework of STEM practices amalgamated from the competencies and practices of science, technology, engineering and mathematics (STEM). This framework, developed for in-service teacher education in the United States, will be adapted for the South African foundation phase context and presented to teachers in a series of workshops. Participating teachers provide insight into their understanding of, reception to, and application of the framework through participatory action research.

Introduction

In the South African curriculum, science and technology education are encompassed within the Beginning Knowledge curriculum programme section (CAPS 2011). Beni, Stears, and James (2012) found South African foundation level teachers to be confident in presenting content with which they were familiar but reluctant to introduce new science topics or instructional strategies. Teachers may not know how to develop science and technology lessons given the structure of the CAPS (Life Skills) document that provides little guidance (pg. 8). CAPS documents are based on the National Curriculum Statements (2002), applying the following Learning Outcomes: learners should be able to (1) apply science process skills in science investigations and (2) apply the technological process to a problem by investigating possible solutions, designing a solution (system, process or product), and finally evaluating and communicating both the process and solution.

We posit that a STEM practices approach is appropriate for the foundation phase Life Skills programme that was intended as an integrated programme. We introduce teachers to the STEM practices framework to prompt re-conceptualization of STEM and application to learning and teaching.

Literature review
The STEM practices framework resulted from reviewing documents that characterize student practices in STEM (Salinas 2018), including the Next Generation Science Standards (NGSS Lead States 2013), the K-12 Computer Science Framework (2016), the Common Core State Standards (2010), and recent publications on engineering education (National Research Council 2012; Moore, Glancy, Tank, Kersten, & Smith 2014). Salinas noticed that certain practices lie at the intersection of the four STEM areas, providing target practices that can be engaged in integrated STEM activities. From this perspective, STEM education is a distinct learning area, informing how we view related skills and competencies, rather than the union of four different learning areas or contrived contextual problem solving.

Internationally, STEM integration has been adopted to varying degrees. For teacher educators, the problem of adoption of STEM integration as a teaching approach is challenging because perspectives vary widely in scope and specificity (English, 2017). STEM education in South Africa has only recently been debated at a national level (National Science and Technology Forum 2018). We aim to understand STEM-related teacher change processes and teacher education practices in the face of South African curriculum change and subsequent classroom adoption so that deliberations can be intentional, impactful, and sustained.

**Methodology**

We propose to develop a series of workshops for in-service foundation phase teachers in South Africa based on experiences of STEM Leadership programmes in the United States, as well as current research in STEM education (Ring et al 2017; Nadelson et al 2012). Taking a participatory action research approach with workshop participants, we investigate the opportunities and limitations for transforming foundation phase classrooms into STEM classrooms in both South Africa and the United States.

**Way Forward**

The STEM practices framework is applied to the South African foundation phase curriculum to create potential learning progressions that exemplify STEM integration. This requires alignment of current outcomes from the NCS for Natural Sciences, Technology and Mathematics with the central practices of the framework. During workshops, in-service teachers will reflect on their own practice and readiness for implementation of STEM practices in their classrooms. The process results in recommendations for the integration of STEM practices into the curriculum and for scale-up in professional development.
References


National Science and Technology Forum. 6-8 August 2018. NSTF STEM Education and Maths Reform Discussion Forum. Johannesburg, South Africa.


DEVELOPING AN ANALYTICAL FRAMEWORK FOR STUDYING CLASSROOM PRACTICE IN THE TEACHING OF CHEMICAL EQUILIBRIUM

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It has been my experience through working with physical sciences student teachers in a South African university that they do not have holistic understanding of most basic science concepts. Their school leaving results in mathematics and physical sciences form the basis of their admissions into the physical sciences teaching specialization, and they need a minimum of 60% for each of these subjects. This means that their performance is taken as some sort of guarantee that they are capable of pursuing the teacher specialization programme to completion.

However, student teachers do not demonstrate the foundational knowledge they are assumed to have mastered. They are not able to cope with the very content they studied at school, let alone going beyond this level to complete the required content modules. Their partial knowledge reflects that they have no deep understanding of the basic concepts and their relationships in chemistry, which makes it impossible to build on prior knowledge; the foundation is flawed.

It is therefore important to study the source of the problem, and to find out where student teachers’ knowledge is most deficient. This can be achieved by studying the actual teaching that the student teachers receive. From this, we are likely to learn how teachers operate and what they do in their classrooms.

Inferentially, knowing how teachers present different topics will enable us to understand or identify factors that lead to gaps, which student teachers display in science topics. Reviewing the literature, there were limited studies that scrutinise the instructional strategies used in these classrooms.

I believe that studying the instructional strategies used by teachers in-depth would be useful in identifying why our pre-service students who have passed the National Senior Certificate (NSC), have such poor understanding of many chemistry concepts. Understanding why the knowledge gaps exist can also help one to determine means of addressing them in teacher preparation.

The question I asked is: What model of studying teaching environments could be used to study classroom teaching environments in the teaching of chemical equilibrium?

The term “instructional context” is used to refer to the context created by a teacher when teaching a specific topic in the curriculum using a particular instructional strategy (Turner & Meyer, 2000).
From reviewing the literature, it becomes clear that the nature of the topics taught and teachers’ views on what makes instruction effective, may be different, but that they influence each other. The purpose of this study was to gain an in-depth understanding of instruction in science classrooms because learners from most schools emerge with limited knowledge of concepts and related skills.

Methodology

The core of the paper is based on review of various forms of literature contextual to the teaching of chemical equilibrium in Grade 12 in South Africa, where examinations hold high importance. The constructed and adapted framing of instructional context is used to study classroom environment is a school where physical sciences candidates consistently perform well in the subject.

Analysis

The constructional context framing is used to analyse what teachers do and how the constructs relate to each other. Implications of using this model to study classrooms are also discussed.
INCLUSION OF INDIGENOUS KNOWLEDGE DURING A LIFE SKILLS LESSON IN A MULTILINGUAL CLASSROOM WITH PRE-SERVICE FOUNDATION PHASE TEACHERS

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Abstract:
The study was conducted with the B.Ed. Foundation Phase pre-service teachers to inform a transformative learning process within an indigenous knowledge collaboration centered on research related to Local Culture for Understanding Mathematics and Science (LOCUMS). This paper thus reports on an exploratory pedagogical work that included indigenous knowledge (IK) in the Life Skills curriculum of the Foundation Phase pre-service course. It was conducted with 42 pre-service teachers to explore indigenous knowledge practices related to water and hygiene in particular. They were introduced to a LOCUMS perspective, an approach to teaching in ways that actualize local knowledge in a socio-cultural and ecological context. To generate data, an inclusive Mother Tongue literacy approach was used to engage the pre-service teachers in exploring how Nguni hand washing and water collection practices related to the reduction of risk during a simulated cholera epidemic in the area. For data analysis, thematic and inductive approaches were used. The findings of the study revealed that the deliberative action learning around the exploratory enactment of indigenous knowledge practices between classroom and home enabled the participants to relate their experiences in learning transactions that explored practical know-how logic of the indigenous knowledge practices. The study thus recommends that the inclusion of IK in the Foundation Phase has a potential to enable building of bridges between home and school experiences.

Key words: Foundation Phase, Life Skills, Natural Sciences, Indigenous Knowledge, LOCUMS

Introduction

Life Skills is the third stream, alongside Literacy and Numeracy in the Foundation Phase curriculum (Bosman, Davin, Esterhuizen, Govender, Jordaan et al., 2016, Department of Education, 2011). The pre-service course was thus developed as a bilingual course to prepare students to teach young children using isiXhosa and English. Essentially, the course was designed to answer the call for bilingual teachers who are professionally qualified and capable of teaching to the needs of young isiXhosa students in the Foundation Phase.

At the time of this study, the multi-cultural class consisted of 42 pre-service teachers, whose mother tongue was isiXhosa, isiZulu, English and Afrikaans. Ten of these pre-service teachers were English and Afrikaans Mother Tongue speakers with little or no experience with indigenous knowledge.
practices. There were, however, isiXhosa Mother Tongue speakers who also commented that they had little experience of indigenous knowledge practices. They also noted that school children in modern South Africa have a similar life experience and have seldom related Nguni heritage knowledge with the scientific concepts in the Natural Science and Life Skills curriculum.

The study was thus conducted with these pre-service teachers to inform a transformative learning process within an IK collaboration centered on research related to Local Culture for Understanding Mathematics and Science (LOCUMS). This paper thus reports on an exploratory pedagogical work that included indigenous knowledge (IK) in the Life Skills curriculum of the Foundation Phase pre-service course and we sought to answer the following research question:

What are pre-service teachers’ experiences on the integration of everyday hand washing as a disease prevention practice in the FoundationPhase multicultural classroom?

Context of the study

The Nguni historically experienced cholera as a hand-to-hand and hand-to-mouth disease that came to Africa from India with the early seasonal trading on the switching monsoon winds between India and Zanzibar. We contextualized the indigenous knowledge practices (Klein, 2011; Mukwambo, Ngoza & Chikunda, 2014) on how African village cultures had come to develop water collection and hand washing practices that served to exclude diseases. This was contrasted with Europe where cholera was much later scientifically detected in water and was thus treated as a water-borne disease like typhoid. This scientific perspective changed recently as scientists deduced that the natural habitat of the cholera organism is saline (estuaries) so it cannot live in fresh water for long and the main way that it is transmitted in humans is hand-to-mouth. The disease is usually acquired from food contaminated by a person infected with the micro-organism that proliferates in enriched gut fluids so that people get severe diarrhea and die from dehydration if not treated with sugar solution to restore electrolytes and metabolic function. This study thus sought to understand how pre-service Foundation Phase teachers would respond to everyday hand washing as a disease prevention practice, with the hope that this would provide border crossing from home to school science (Aikenhead & Jegede, 1999). Additionally, we had hoped that this would help to illustrate how to make Life Skills and Natural Sciences in particular culturally sensitive (Mhakure & Otulaja, 2017) to these pre-service teachers.

Literature Review

Aikenhead and Jegede (1999) propose that science teachers should always endeavour to make school science relevant to learners’ everyday lives. They refer to this as border crossing, which could be achieved through taking into consideration learners’ prior knowledge. It should be acknowledged,
however, that such prior knowledge could be in the form of local or indigenous knowledge (IK) (Ogunniyi & Ogawa, 2008).

Ogunniyi and Ogawa (2008) remind us that IK is a body of knowledge that is built up by a group of people through generations of living in close contact with nature in a particular community. Shizha (2007) posits that IK enables communities to live in harmony with their environment for generations. To Nyika (2017), such knowledge is passed on from generation to generation but there is a risk that such knowledge might be lost since it is not documented.

**Theoretical Framework and Approach**

The exploratory study was undertaken as a process of participatory approach using Vygotsky’s (1978) socio-cultural theory as a theoretical framework. To Vygotsky, social contexts and interactions during the learning process are critical. That is, learning is understood as a means of active participation as proposed by Sedlacek and Sedova (2017). Ignoring the socio-cultural reality of learners, beliefs, attitudes, values and personal identities might have negative implications on their understanding of science (Lemke, 2001; Mavuru & Ramnarain, 2017). It is precisely for these reasons that we saw the socio-cultural framework as appropriate as a theoretical framework in this study. That is, the LOCUMS enabled social mediation and interactions amongst the pre-service teachers to take place. Within the Vygotskian (1978) perspective, a learning progression (task sequencing) in line with Edwards’s (2014) approach as outlined in Figure 1 below was adopted.

**Figure 1: Shows developmental learning progression in Education for Sustainable Development. Adapted, Edwards (2014)**

The contours of the mediated17 student inquiry, deliberative learning (retroductive inferences) and application of the emergent knowledge (retrodictive inferences)22 served to steer everyday health

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17 Here we use mediation in a Vygotskian sense of teacher scaffolding of the learning transactions as well as the fabric of the socio-cultural signifiers in a world of real objects that have mediating power.

22 The nexus juxtaposing of retrodiction and retrodiction is an analytical and pedagogical reduction for a more nuanced, open-ended and complex transformative learning process.
practices at a narrative level that was significant to the participating pre-service teachers. Contemplating inquiry processes such as these Bhaskar notes:

The contingent duality (and simultaneity) of discovery and application, together with that of the (again contingent) co-incidence of retroductive and retrodictive moments in research. (Bhaskar, 2016, p.80.)

Chikamori and Tanimura (2018) elegantly draw on these Critical Realist insights into human enquiry and transformative action to propose a Transformative Model of Education for Sustainable Development (TMESD). This is a departure from an instrumental functionalism in ESD, which has been widely critiqued (Jickling & Wals, 2012). The framing of a TMESD transcends this problem and has resonance with the mediated learning progresses in this collaborative IK work where the pre-service teachers in an everyday pedagogical exploration of indigenous knowledge practices developed insights to derive better practices for reducing health risk. From his insights into transformative social processes of scientific enquiry in/as everyday human ‘exploratory investigation’, Bhaskar proposes a model involving:

Resolution, abductive redescription, retrodution (RRR)
Inferences to the best explanation - most plausible mechanisms or complex (I)
Retrodiction, elimination, identification of antecedents and correction (R E I(C)).

(Bhaskar, 2016, p. 81)

Bhaskar differentiated this possibility around a (contingent) concurrence across retroductive and retrodictive moments (Price & Martin, 2018). In the learning transactions with the pre-service teachers, abductive insights appeared to shape the stimulation of explanatory propositions and these had the knock-on effect of generating retrodictive projections towards relating what might best be done for health, wellbeing and the common good.

Methodology

A qualitative case study approach was adopted in this study (Bertram & Christiansen, 2015; Cohen, Manion & Morrison, 2018) in order to access in-depth information on the indigenous knowledge practices around water collection and hand washing. It was conducted with 42 B.Ed. Foundation Phase pre-service teachers as part of their Life Skills education program in their second year of study. The lesson opened with a lecturer contextualizing the topic and using a story-telling approach to describe the origins of cholera in eastern southern Africa to model the indigenous knowledge practices as everyday know-how. Here, English language video materials were used to relate and model indigenous knowledge practices around water collection and hand washing.

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23 This proposition was explored in a recent research seminar at Naruto University, Japan and the contours of a research collaboration in ESD and IK pedagogy were sketched by the participants.
The participating pre-service were then given inquiry challenges to deliberate on water collection or hand washing. Mother Tongue speakers, working in isiXhosa, role played young learners going home into a rural community context after seeing the video and speaking to their parents and the elderly as custodians of the indigenous knowledge practices being explored. Their task was to undertake a community inquiry that would enable them to develop a structured dramatization in which their learners would enact and recount the selected indigenous knowledge practices in isiXhosa Mother Tongue the following day.

The group role-play enactment of the knowledge practices in isiXhosa was an engaging process. The inquiry and enactment was then extended into an explanatory deliberation with simultaneous translation back into English, giving the pre-service teachers plural language development experience. In this way and at this stage of their multilingual classroom pedagogical work, they experienced the deliberative acquisition of the necessary vocabulary and knowledge practices (words, concepts and actions).

Finally, the knowledge practices extended to the participants being challenged to relate the indigenous knowledge to healthy ways of using water in the present day. The latter task was explored as the assessment task to explore language acquisition and grasp of concepts. This completed the learning progression that developed from the acquisition of vocabulary in the video, through structured Mother tongue enactment to an explanatory relating of the indigenous knowledge practices to desirable present-day health practices in school and at home.

**Findings and Discussions**

The deliberative action learning around the exploratory enactment of indigenous knowledge practices between classroom and home enabled the participants to relate their experiences in learning transactions that explored:

- **A practical know-how logic of the indigenous knowledge practices**
  In the enactment of the activities, the participants were surprised that the underlying logic of the pouring hand washing with drip dry was a healthier approach that washing in a basin and using a towel.

- **Relating heritage practices to scientific concepts in explanatory work**
  As the activity developed and the participants deliberated how and why indigenous practices were healthy, they drew on their everyday and scientific knowledge to generate explanations in their groups.

- **How the learning related to the healthy use of water today**
  Here the most effective was hand washing as it relates to much of what teachers of young children build into the snack and toilet routines of the school day.
The two-way inquiry work between intergenerational knowledge practices and scientific concepts surfaced a dimension of life-experience and identity-centered meaning making (Cocks, Alexander & Dold, 2012) that enabled participants to enter the arena of knowledge production to inform health practices in the modern day. The associated learning and transformative modelling was evident in the classroom narrative where the pre-service teachers related past knowledge practices, the concepts of science and what would explain and justify their hand-washing practices as well as appreciations of how disease-free potable water comes to us today.

The task sequencing worked well in the lecture situation, enabling progressive concept and practices clarification but the activity had high novelty value so the pedagogical task sequencing was not made as explicit as we had planned. Notwithstanding, the pre-service teachers expressed an amazement that the depth of indigenous knowledge practices was both simple and practical for excluding the risk of disease, some noting that they had a new respect and pride in being Xhosa (Cocks et al., 2012; Webb, 2013).

Concluding remarks and Implications

This exploratory study was useful for opening up ways of relating indigenous knowledge practices, scientific concepts in the curriculum and health practices in the present day. However, the task sequencing could have been made more explicit to exemplify the need for active presentation and modelling in language by the teachers to enable the open-ended acquisition of blended propositions (ontological life experiences of pre-service teachers and the cultural capital of indigenous knowledge and scientific institutions)\(^2\). This deliberative process was foundational to the participatory learning that followed and laid the ground for the more independent relating of the knowledge acquired to everyday hand washing as a disease prevention practice.

At the outset, the participating pre-service teachers assumed that there was a clear difference between indigenous and scientific knowledge. They were also uncertain about the value of the former in a modern everyday and classroom contexts. What the exploratory work opened up was that they came to develop a new respect for historical cultural practices that have been largely forgotten but could be brought into the classroom context to:

- build self-respect and respect for Xhosa knowledge practices;
- introduce new words or concepts in both languages building bilingual fluency in active and engaging ways; and
- to foster inquiry and deliberative meaning making as a successive and deepening process related to human wellbeing and sustainable living.

\(^2\) These intersecting processes and developing process skills of inquiry and deliberative meaning-making reflect the nexus of discovery and application (reductive and retrodictive inferences) discussed later in the paper. Emerging insights enabled the framing the next round of research at the interface of life experience, indigenous knowledge practices, the scientific knowledge of the Life Skills curriculum and questions related to healthy lifestyle choices.
References


LEARNERS VIEWS ON INTEGRATING TRADITIONAL MEDICINE INTO A LIFE SCIENCES CURRICULUM
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Abstract
The proposal found in the South African Schools science educational policy advocates for the integration of science and Indigenous Knowledge Systems with a view to purge the education inequalities that were created by the apartheid education system (Jansen, 1998; Msila, 2007). This proposal is intended to promote the teaching and learning of science within the context of historical, societal and cultural knowledge systems and values. The paper explores conceptions held by Grade 10 Learners about traditional medicinal plants and their attitudes towards its specific integration into the Life Sciences Curriculum. A mixed methods approach for gathering data through a class survey and focus group interviews is used in a one-shot research design. Preliminary results indicate a favourable view towards this integration and understanding of the value of traditional medicinal plants.

Keywords: Traditional medicine, Integration, Indigenous Knowledge, Life Sciences

Introduction: Theory and Literature

South African Science Education Policy since 2001 redresses imbalances of apartheid education. Multiculturalism according to Gay (n.d.) is a conceptual, framework, a way of thinking, a philosophical viewpoint, a value orientation and a set criterion for making decisions that serve the educational needs of a culturally diverse student population. In science education this theory brings about cultural diversity. This means that what the learners have to offer is, not rejected or belittled simply because it differs from what the majority or those in power, regard as important and of value, but accommodates different worldviews and ideas that the learners bring into the classroom without marginalising the learners’ indigenous knowledge or existing knowledge (Rosando, 1996).

Cultural Border Crossing Theory

Learners come to school holding different perspective about how the world works. Such knowledge needs to be valued because it plays a pivotal role in student development. According to Aikenhead (1999, 2009 & 2001) when learners learn science, they transcend between their everyday life world and the world of school science. The movement between learner’s everyday life to the world of
science is conceptualised as cultural border crossing and the role of teachers is to assist the learner in crossing easily and smoothly.

Jegede and Aikenhead (1999) proposed a spectrum of cognitive experiences which include parallel, simultaneous, dependent, and secured collateral learning, to explain cultural border crossings. This theory of Jegede (1999) is used as an analytical lens to interrogate responses to the research questions.

Parallel collateral. In this category the pupil will access one schemata or the other depending upon the context. For example, in the process of biotechnology, the pupil will use the scientific knowledge only at school, never in their everyday world.

Secured collateral learning. In this category the conflicting schemata consciously interact and the conflict is resolved in some manner. The person will have developed a satisfactory reason for holding to both schemata even though the schemata may appear to conflict, or else the person will have achieved a convergence towards commonality by one schema reinforcing the other resulting in new conception in long term memory.

Dependent collateral learning occurs when a schema from one worldview or domain of knowledge challenges another schema from a different worldview or domain of knowledge, to an extent that permits the student to modify an existing schema without radically restructuring the existing worldview or domain of knowledge.

Simultaneous Collateral learning occurs when the science concept is held by the learner in his or her prior knowledge, this occurs when there is no interaction between a learners’ worldview and that of science.

Significance
The study seeks to determine grade 10 learners’ views on the inclusion of indigenous knowledge topics, such as traditional medicines in a Life Sciences curriculum.

Research questions
This study seeks to answer the following questions:

1. What are the conceptions of grade 10 learners towards the use of traditional medicine to cure ailments?
2. What are the views of grade 10 learners towards the inclusion of a study on traditional medicines in the Life Sciences curriculum?

Methodology
A mixed methods research design approach in which qualitative and quantitative methods, techniques, or other paradigm characteristics, are used (Creswell, 2003). This method has value in that it capacitates different cultural representations present in the selected sample.

The sample consists of 40 grade 10 life science learners comprised of two classes of 20. These learners were briefed on the significance of the study, and were given the option of responding in their vernacular language (mainly isiXhosa). Ethical considerations were carefully considered and all necessary consent forms were obtained. Data was collected through a survey type questionnaire consisting of relevant statements highlighting traditional medicine usage. Learners were also interviewed to gain a richer understanding of their views.

To ensure validity and reliability all the instruments were given to five experienced science teachers, four student colleagues and the lecturer for scrutiny purposes. They were to assess the appropriateness of statements and the clarity of the questions; to check for overlapping questions and whether the content is pegged at the level of the learners’ linguistic abilities (Magerman, 2001). Each question/statement was rated on a scale of 1 to 10: 1 = weak to 10 = strong; for the validity calculation.

**Findings**

The following graph shows the ailments treated as indicated by the grade 10 learners using traditional medicinal plants. Fever is recorded as the highest ailment (80%) being treated. Interviews with learners reveal much about their knowledge of the plant used, its processing and its usage.

*Table 1: Ailments treated using traditional medicinal plants*

<table>
<thead>
<tr>
<th>Disease</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fever</td>
<td>80%</td>
</tr>
<tr>
<td>Wounds</td>
<td>50%</td>
</tr>
<tr>
<td>Headache</td>
<td>30%</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>20%</td>
</tr>
</tbody>
</table>

Learner 2: “The medicinal plant I used was the “umhlonyana” plant which I boiled and drank it, it is better known as Artemisia afra’
Learner 14: “I have boiled plant called umhlonyana in water and drank it”
Learner 17: “Take a piece of umhlonyana and boil it in the water for several times then drink it”
From these responses lamented above one could easily gasp that these learners do not just know the plants used to treat fever, but they are also aware of the method used when preparing these medicinal plants. That might be something they have seen their parents doing or something they were taught by their parents. *(Dependent Collateral Learning)*

In the questionnaires learners were also asked to provide a definition of the concept ‘traditional medicinal plants’ to test their conceptions. The learners seem to have an understanding of the concept “traditional medicinal plants”. In responding to this question, learners provided the following definitions:

*Learner 9:* “Traditional medicinal plants are plants that come from nature used in other times” *(Simultaneous Collateral)*

*Learner 14:* Plants that are indigenous plants that are used by our forefathers to treat wounds and disease or illness. *(Simultaneous Collateral)*

From the definition designated above it is evident that these learners acquired knowledge from their parents. For example, Learner 2 when she was asked to name cultural activities on which traditional medicinal plants responded as follows:

“Ipepho is used when people want to consult or communicate with their ancestors or when there is cultural activity called Imbeleko (a ceremony conducted when a baby is born). Where the main person inhales and exhales the impepho (incense)” *(Secured Collateral Learning)*

Learner number 4 said “Imbeleko – when a child is introduced to the family ancestors. Intonjane- when a girl is said to be traditionally circumcised” *(Secured Collateral learning)*

From these responses one could easily notice that this knowledge the learners have about traditional medicinal plants is an acquisition learned through direct observation or oral communication.

**Conclusions**

This study may assist in strengthening the awareness of recognising the value of including indigenous knowledge in the sciences thus eliminating biases and marginalisation of indigenous knowledge. The study contributes to teachers understanding of the role and the significance of indigenous knowledge in science education. This study raises learners’ awareness about the significance of traditional medicinal plants.

**References**

CAN INSTRUCTION IN SOCIOSCIENTIFIC ISSUES BUILD HIGH SCHOOL STUDENTS’ NATURE OF SCIENCE CONCEPTIONS?

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Problem:

The National Research Council stated that a primary goal for American science education is a scientifically literate person who can understand the nature of science (NOS). Scientific literacy and NOS are linked in the Next Generation Science Standards as “the integration of scientific and engineering practices, disciplinary core ideas, and crosscutting concepts set the stage for teaching and learning about nature of science” (NGSS, 2013). While the national mandate has been to convey the framework of NOS aspects to students, the challenge continues to be determining how to do it best in the classroom. Socioscientific issues (SSI) are open-ended, ill-structured, debatable problems that involve multiple perspectives and interpretation (Sadler & Zeidler, 2005). SSI have been established as an effective context for development of knowledge and processes contributing to scientific literacy, including evidenced-based argumentation, consensus building, moral reasoning, and understanding and application of science content knowledge (Sadler, 2009; Zeidler & Sadler, 2011). Research studies have been considering the relationship between NOS aspects and SSI contexts for the last 20 years. The research question for this study was: How does secondary students’ understanding of nature of science change using explicit-reflective strategies within a SSI context?

Design/Procedure:

This study provided lessons plans with multiple exposures on SSI to teach NOS aspects in an explicit and reflective way. The subjects were 10 students with no familiarity with NOS aspects attending high school in a large city in the US Midwest. The VNOS D+ questionnaire (Lederman et al, 2002) was given twice to determine change in understanding of NOS by students’ pre to post test. The aspects studied were tentativeness, creativity, observation & inference, socially & culturally embedded, subjectivity, functions & relationships of theory and law, and empirically based. In addition to the VNOS D+ data, lesson plans, teacher artifacts, classroom observations, student artifacts, and follow-up student interviews were analyzed over 11 weeks in 2015.

Findings/Analysis:
The researcher analyzed all data sources: lesson plans, teacher handouts, student artifacts, observation notes, and VNOS D+ results. Each aspect of NOS was tallied with references to NOS overall coded as generic. The lesson plans contained 91 explicit references to NOS, while there were only 21 explicit NOS references made by the teacher across four lessons. The disparity lead the researcher to compare the time planned for explicit NOS reflection (32%) and the time actually spent reflecting (17%). The number of NOS references made by students in their work were recorded and coded for each aspect. There were 80 explicit references to aspects of NOS from student artifacts. Coding was compared with two peers until inter-rater reliability was established (>80%).

The primary data source used to determine if students’ understanding of aspects of NOS changed was the VNOS D+. Pearson’s chi square test could not be applied, as the actual sample size was so small that in 75% of the data reviewed, the frequencies were less than five. A more robust test was used to determine significance, the Fisher’s Exact Test. The number of tests of significance performed raised the issue of Type I error. Changes in students’ understanding were significant with an alpha of 0.05 for four of the seven aspects. The range of FET reported p-values that were 0.0108 for the aspect of tentativeness, 0.0003 for the aspect of creativity, 0.0197 for observation & inference, and 0.0376 for empirically based. Students did gain in their understanding of NOS aspects in a SSI context in this study!

Conclusion/Implications:

This study was encouraging. Despite limited references directly from the teacher, students can gain in their understanding of NOS aspects with some form of dedicated reflection. The actual time devoted to the explicit reflection of NOS aspects was half of the planned time, so imagine the potential impact the allocated time could have on increasing students’ understanding. Despite limitations, such as small sample size and short duration of study, all seven of the aspects of NOS had a percentage increase in student understanding, although changes in students’ understanding were statistically significant with an alpha of 0.05 for four of the seven aspects.

Although NOS aspects were explicitly taught through classroom activities and teacher made artifacts, the aspects of NOS that demonstrated the greatest gains in understanding were the aspects that were individually referenced in lesson plans, observations, and student made artifacts. While there were modest changes in understanding from naïve to mixed, few students’ understandings were categorized as informed. Students’ understanding of nature of science did change with explicit instruction and reflection on certain NOS aspects, which is consistent with the findings reported by Khishfe and Abd-El-Khalick (2002) and Lederman et al (2014). The teacher did not make explicit statements about NOS aspects, did not have time to ask students about their questions, to discuss their responses with the class as a whole, nor had students cite specific examples from their activity experience. This is similar to findings by the Schwartz et al (2002), which found that often teachers make implicit references to NOS, but then make the assumption that the aspects were clearly
understood by the students. There were infrequent explicit comments about the aspects because the teacher thought the students understood said aspects simply by stating them. This study shows that not only does information need to be explicitly taught, but students also need time to discuss and write about the information specifically in order for an increased understanding to be reached.

The study results support the understanding that for teachers to change students’ understanding of NOS aspects, they must explicitly plan and reflect on each individual aspect. While planning, it is critical to identify where in the lesson and which specific aspects of NOS will be addressed. Ensuring time for the process needed to establish the SSI context, more time is needed to adequately provide for explicit reflection on the NOS aspects. This reflection section should include intentional questions and possible answers from students at all levels of understanding based on the NOS connections make during a specific SSI lesson. It is well known that NOS is often absent from classroom activities. With the growing adoption of the NGSS standards, teachers will need to intentionally plan for including NOS aspects in the curriculum.

Teacher education programs can support promoting students’ understanding of NOS aspects by providing pre-service and inservice teachers opportunities to plan explicitly and reflectively in lessons for overt instruction in NOS. Lesson plans work best when they reflect specific aspects of NOS and how the teacher addresses the aspects and the responses students might give to their planned questions. It is important to recognize the importance of focused professional development and ongoing support on teachers’ efforts to include NOS among their instructional practices.

Future studies could examine how different types of explicit/reflective student activities focusing on NOS aspects impact student understandings. By examining student activities, it could inform how the activity of reflection, both orally and in writing, influences specific aspects of NOS. The analysis of student activities would also allow for comparison of when in the lesson the explicit NOS instruction is best suited. Such a study could consider if timing within a lesson of NOS statements affects students’ understanding of NOS aspects. Another study could continue using a SSI approach to teaching content and NOS aspects.

References


THE ARGUMENTATION IN EXPERIMENTAL ACTIVITIES: Assessment of the Ability of Argumentation in Teaching Students Chemistry
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Abstract
Several publications on argumentation emphasize its importance in science teaching, although experimental activities may provide better environment for constructing a scientific argument little is known about its influence on the quality of arguments that students can formulate when solving an experimental problem. This current study aims at assessing the reasoning capacity in terms of experimental activities of third year students of BA in Teaching of Chemistry, from the following experimental problem: why does the candle flame disappear when it is covered up burning? The problem was discussed with students after a demonstration experiment on combustion and intervening factors using local material, and Toulmin model was used to analyze the argument constructed by the students, combined with another adapted from Ogunniyi. The results revealed that the students present arguments that are almost logical and argument by logical definition, showing elements such as "conclusion", "justification" with logic and "refutation" implicitly though. They presented lower quality argument in experimental activities to the detriment of theoretical subjects because the teaching strategy, the type of content and its relevance may have influenced the quality of the students' argument.

Keywords: Argumentation, experimental activity, argumentative capacity, chemistry teaching.

Introduction

The new research trends in education, with the main attention in the area of sciences, have shown the importance of developing work in the area of interface management concerning the teaching-learning process. For this, the contribution of speech and writing, or rather of scientific language in the development of reflexive discourses, is unquestionable, considering the fundamental argument for the development of discourse. Although its relevance to science teaching and learning processes is recognized, the argumentation has been described as practically non-existent. (Queiroz & Sá, 2009).

Before the challenges of the Teaching and Learning Process in the present time, different researchers have developed several studies on the need to prioritize the strategies of argumentation, (Oliveira, 2012; Sá, 2010; Queiroz & Souza, 2007; Queiroz & Souza, 2013; Fatareli & Ferreira & Queiroz, 2009 and Marconde & Suart, 2010) particularly in the field of Natural Sciences, hence the organization of
classes in which students have the opportunity to practice it becomes fundamental. When the students argue, develops the analytical spirit in the confident choice between the different alternatives from the various sources of information and the various explanatory models for the process involved (Sá, 2010, p.08), and this will give him more and more the capacity of critical thinking.

The study of chemistry is based on substances and their transformations with the aim of developing in the student the ability to interpret the world scientifically, explaining from a chemical point of view the movement of matter and to enable them to correctly use theories and laws in resolution of practical problems and in explaining the phenomena that occur in nature. Marconde and Suart (2000) emphasize “that the experimental investigative activity may allow these objectives to be achieved since it prioritizes the more active participation of the learner in solving problem mediated by the teacher” (p.02). Students have the opportunity to elaborate hypotheses, analyze the data, propose conclusions and expose these thoughts to colleagues and teachers. In this way, I consider the study as a trigger for the improvement of students' argumentative capacity and for discussions on scientific topics related to school experiences. So the great challenge of this study is to implement activities which can persuade the students to produce arguments for scientific explanations in the context of an experimental activity.

The present study was oriented to answer the following starting question: what is the students' capacity for argumentation about experimental activities? The study's general objective is to evaluate the students' capacity of argumentation in experimental activities during a class of Didactics of Chemistry III which dealt with combustion and the intervening factors. Specifically, the study aimed to identify the type of the arguments made by the students; to describe the difficulties that students face in the construction of the argument and to assess the quality of the arguments produced by them.

Methodology

The present qualitative research was carried out in BA in Teaching of Chemistry in the classes of Didactics of Chemistry III, the acquisition of knowledge by the experimental activity and chemical experiment on the combustion of the substances and intervening factors was developed. The students discussed in three formed groups, with five elements in each, solving tasks after the experimental activity. The group work was oriented in a cooperative way because during presentation of the arguments the teachers made individual classification of each participant, although they had produced a collective argument. In cooperative learning it is expected that students in small groups will perform a task without direct teacher supervision. However, several codes have been assigned, G31, G32 and G33.

Procedures for collecting survey data

a) Capturing students' arguments.
The school thematic concerning experiences and laboratory practice on combustion and factors influencing the combustion of substances were selected in the class of third year of BA in Chemistry teaching to create the argument space. The students were asked to discuss in a group to find answers to the problem posed by the teacher, and as the students presented the answer of the problem in plenary, he was going to get together with the teacher the argument of each group that at the end of the lesson was delivered in writing for a better analysis. This process occurred in two different moments, before and after the teaching of the technique.

b) *Teaching the technique of argumentation to students.*

A lecture was held on the concept of argument where elements and characteristics of a quality argument were evidenced. There was explanation from concrete examples, using the Toulmin model useful for classifying the argument according to the constituent elements.

c) *Elaboration of a Learning portfolio*

Students were instructed to reflect on their learning, on the strengths and weaknesses of their experience in constructing arguments. The fundamental goal of the learning portfolio was to gather information about the course of student learning as well as to help clarify the argument produced. To this end, the following guiding questions were prepared in order to draw student's attention to reflection: which activities aroused more your attention? What activities did you find most difficult to accomplish? And to what extent did the construction of arguments facilitate student learning?

d) *Analysis and evaluation of the quality of students' arguments*

To evaluate the quality of the argument, we used the model link of Toulmin establishing the elements of the argument, having been useful to check if students have in their argument the following: Data (D); Conclusion (C); Justification (J); Refutation (R) and Basic Knowledge (B), Combined with another adapted from Ogunniyi which classifies the quality of arguments into six levels according to the characteristic of each argument as illustrated in the table below:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>No opposition</td>
<td>0</td>
</tr>
<tr>
<td>Claims but without foundation and no refutations</td>
<td>1</td>
</tr>
<tr>
<td>Claims with ground but without refutations</td>
<td>2</td>
</tr>
<tr>
<td>Claims with basis and a refutation contesting claim</td>
<td>3</td>
</tr>
<tr>
<td>Multiple refutations contesting allegation but none defying the fundamentals</td>
<td>4</td>
</tr>
<tr>
<td>Multiple refutation contesting claims with just one challenging basics</td>
<td>5</td>
</tr>
<tr>
<td>Multiple refutations defying the fundamentals</td>
<td>6</td>
</tr>
</tbody>
</table>

**Results and Discussion**

*Arguments Presented Before Teaching the Argumentative Technique*
For the class of school experiences in chemistry teaching, the students discussed and proved the following: Schools that do not have laboratory and laboratory materials did not perform practical classes.

Students G³¹ presenting the following argument transcribed as follows: This statement is not true, because not all schools or teachers cross hands waiting for laboratory equipment and buildings, some teachers have been struggling to make other practices using easily accessible material. In this argument the following information has been identified as a refutation: [... not all teachers cross hands waiting for equipment and laboratory buildings ....] And basic knowledge the following: [... some teachers have been striving for practical classes with resource of easy access ...].

The G³² wrote his argument quite extensively where only a few useful extracts were extracted for our analysis, since it clearly shows two refutations: [...There are teachers who carry out experiments without laboratory and laboratory material ...and there are schools with a laboratory, but teachers do not take practical classes ...].

G³³, also presents its argument in an extensive way, to be highlighted: refutation 1: not all practices require conventional materials and laboratory; Refutation 2: experiences are not carried out due to lack of creativity of teachers associated with neglect and lack of mastery; and conclusion: in schools without laboratory and materials one can, yes, carry out experiments.

Teaching Argumentative Techniques to Students
As it was referenced in the methodology, a lecture on argumentative techniques was carried out, aiming to determine if the knowledge about argumentation is determinant in the ability of the students to argue after having been put to make argument without the knowledge of these. Through the observation and auscultation during the lecture, it was noticed that the materials were divulged before the students and some revealed that with this information, they would have done the best in the activities in charge. It was also useful for a comparison between the arguments before and after the teaching of the technique.

Arguments Presented After Teaching the Argumentative Technique
After the lecture, arguments were raised during the practical lecture about factors that intervene in the combustion of substances; students had to explain and argue about the factors that influence combustion, having posed the following question: why does the candle flame disappear in a process in which the candle in combustion is covered?

G³¹ presents as Data or evidence: the candle; Conclusion: Immediate disappearance of the candle flame; Justification: when the candle is covered by the glass turns off because there is the absence of
oxiding carbon dioxide; Refutation: there is a lack of elements / substances: oxidizer, fuel and activation energy, therefore combustion does not occur; Basic Knowledge: For combustion to occur it must contain all substances.

It can be observed that this group confused almost everything, because by the analysis one can consider the Conclusion as Data and Basic Knowledge as Refutation, and vice versa. And in the justification, it identifies carbon dioxide as oxidizer, but it is known that this substance extinguishes the flame, for that reason it is used in fire extinguishers. How could he in this case feed the flame?

In sequence, $G^{32}$ bears the same refutation and basic Knowledge which the first group, and Data displays as: candle combustion; Conclusion: the flame disappears immediately; Justification: covering the cup candle goes out because we note the absence of the oxidant.

$G^{33}$ conclusion as features and similarity in the previous group, Justification different depending on the substance which is absent in the process and an Refutation different to those already presented above, where it is clarified that the combustion ends not only because the oxidant is absent. There are also other factors that participate in the combustion, such as: fuel and activation energy.

The three groups are the five elements of the argument, with the exception of $G^{33}$ that does not have the basic knowledge, but reading his Refutation is noticed that the students put the two on a single element however. The groups no longer present more than one refutation as they did so unconsciously before the teaching of the argumentative technique.

**Presentation of Student Portfolios**

In this part we present and analyze the portfolios that the students elaborated evaluating the work developed, highlighting successes and difficulties faced in dealing with argumentative techniques.

$G^{31}$ emphasized that "constructing an argument about the first subject related to school experiences was much easier than constructing an argument about the subject matter of the demonstration experiment on factors involved in combustion." Nevertheless, they liked to have learned with the argumentative technique because they clarify, "to learn thus helps to consolidate and leaves no doubt on the matter".

$G^{32}$ says "learning by arguing is important because it helps to explain the matter in any way possible", explaining that studying arguing leaves no ambiguity about the learned subject. However, it reveals that had difficulty in elaborating the rebuttals.

$G^{33}$ reveals clearly in its portfolio that students liked to have learned to build arguments as they say "the construction of arguments facilitated learning as it gives the organization and helps explain briefly the matter" however, find it more difficult to draw up the basic knowledge, they comment:
formulate the very argument that is the justification is not difficult, the most difficult is the basic knowledge.

Assessment of the Quality of Students' Arguments

There is a setback in terms of the quality of the arguments constructed by the students, since in the first phase even before the teaching of the technique they were able to construct arguments of the highest possible level. However, this ability to argument failed to display the back, even having learned about the techniques of argumentation. This means that the knowledge of the argumentative technique did not significantly influence the quality of the argument.

This situation may have been conditioned by many factors highlighting three (teaching strategy, type and content relevance) but without ignoring other possible. Group work may have been very decisive, since in this activity students may not have worked together putting separate students (from those who produced prior to the teaching of the technique) to produce arguments at this stage. As it was not the same students elaborating the argument they did not manage to evolve in argumentative discourse. Along with this, Kutnick argues that the efficiency of the cooperative method depends on the type of interaction within the group (as cited in Barbosa & Jófili, 2004).

The other factor not least, is the meaning or relevance of knowledge to the student. It may be that the subject of scholarly experiences in general has meant more to the student than the subject of chemical combustion experience and intervening factors, having facilitated the fixation of matter in the cognitive structure and consequently provided meaningful learning. The type of content in which the student must construct the argument may also be quite determinant in the quality of the argument he produced, since it was easier for the student to construct an argument on theoretical matter and a detriment of practical matter.

As far as argumentative techniques are concerned, all students tended to construct almost logical and argument-by-definition arguments.

The quality of the arguments that students present is average, with more frequency at levels three (3) and six (6), with implicit elements. Justification with logic and multiple Refutations before the teaching of the argumentative technique and, explicit elements, justification without logic and a refutation, after the technique. On the whole, the students found it difficult to engage in the development of reading and the organization of reasoning, which made them not evolve in the arguments; therefore, conditions were created, from the availability of scientific knowledge to the procedure of providing the answer to the question posed.

The question of reasoning and argumentative discourse was explored by Jimenez - Aleixandre and Bustamente (2003) where they concluded that there is a greater dependence on the ability to reason for the capacity to argue. The reasoning is the inner discourse linked to abstract questions and this
acts as an incubator or bridge to a well-elaborated argumentative discourse, thus avoiding spontaneous discourse. Spontaneous discourse in situations in which a problem is discussed in the classroom may reveal statements that are not totally correct, but useful in the construction of knowledge, on the other hand (Jimenez - Aleixandre & Bustamante, 2003). Therefore, even if the student's response does not correspond symmetrically with the scientific knowledge about the content addressed, it is able to show the student's reasoning and capacity for understanding.

There were students (although few) who deepened their reading through logical reasoning and critical thinking about the transmitted subject, and they managed to have a very well elaborated argument and with more than one refutation. According to Amelsvoortetetal when students go deeper into a topic, they not only say whether something is indicated or not, but rather provide examples, counter-argument and refute (as quoted in Queiroz and Souza, 2013).

Conclusions

The type of argument presented by the students is usually by logical definition, grouped in the almost logical arguments, without much evidence of the essential elements of argument and without multiple refutations defying justification, occupying the middle level of argument quality classification.

The students' greatest difficulty was in the good use of reading, removing essential aspects for the construction of the argument. If they had grasped the basic knowledge during the reading, they would not have so much difficulty because the characteristic and elements of the argument is a form of representation of the learning. They also had difficulties in arguing about practical subjects, in which the experience was applied as a method, to the detriment of the theoretical ones, where the experience was as content because they presented lesser argument in the experimental activities.

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IS PCK EXPOSURE TO PHYSICAL SCIENCE PGCE STUDENTS ENOUGH FOR QUALITY TEACHING?

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Abstract

Teacher quality matters. As stated by Kind (2016) “pedagogical content knowledge...offers a potential contribution to developing high quality science teacher education” (p.123). This study explored the relationship between the developing espoused TSPCK of PGCE pre-service teachers and their classroom practice (enacted TSPCK). According to Kind (2016), teachers have to be educated effectively if they are expected to promote student achievement. A PGCE teacher development program is typically a one-year program that hosts pre-service teachers who have completed a non-teaching qualification degree and have switched into a teaching career. This study focused on a cohort of eight (8) 2018 PGCE physical science pre-service teachers registered for a chemistry methodology course. The class had explicit discussions of the knowledge for transforming content knowledge of chemical equilibrium. Data collected constituted a set of pre, intermediate and post CoRes on chemical equilibrium, accompanied by 2 video recorded lessons delivered by three (3) pre-service teachers on the topic. The analysis of collected data was mainly in-depth qualitative analysis for evidence of TSPCK, represented for comparison pictorially using a TSPCK Map (Park & Chen, 2012). Explicit links between the evidence of developing TSPCK during the coursework and that seen in the enacted classroom were highlighted. The findings revealed: a visible learning progression across the intervention; the quality of the teachers’ espoused TSPCK grew remarkably from basic to developing after the treatment. The links in the pre-service teachers’ espoused TSPCK level was evident in their teaching with their enacted TSPCK mainly at a proficient level. An argument for what is to be considered for description of quality teaching from the TSPCK perspective is presented.

Introduction:

“Too many children are emerging from school without the education that they need...” (Stutchbury, 2014, p. 1). The students’ poor performance in mathematics and physical science in South Africa has been attributed to the teachers’ incompetence (Makgato & Mji, 2006). As we continue in South Africa to train teachers through two main streams, one being a 4-year B Ed degree, and one being the PGCE stream who undergo a 1 year fulltime programme, the concern arises about the adequacy of their training. For South Africa to survive this tragedy of poor learner performance in science, it needs qualified teachers who are knowledgeable in science and have been taught accordingly so. Initial teacher training institutions are therefore under pressure to produce science teachers who are highly motivated, hardworking, and of high quality; who can teach for learner understanding and thus
improve the quality of education that South Africa needs (Witzig & Sickel, 2016). Unless teacher training institutions begin to understand the core, practices needed by PGCE as a special group of pre-service teachers, and also understand the ways in which this group learns, transfers and use their knowledge, the production of high calibre physical science teachers as needed by the current crisis will remain a dream. Poor learner performance in physical science will also persist.

With researchers emphasizing more on the importance of introducing pre-service teachers to different practices expert science teachers use (Grossman, Hammerness & Mcdonald, 2009), the issue of period of exposure comes to play when PGCE student teachers are concerned. One of the core practices in science education is PCK - the development of knowledge to transform content into a form that learners can comprehend. Many attest to the significance of implementing PCK construct in the teacher training programmes (Aydin, Demirdogen, Atkin, Uzuntiryaki- Kondakci, & Tarkin, 2015), more specifically the topic specific PCK (TSPCK) (Mavhunga & Rollnick, 2013). This study explored the exposure of PGCE student teachers to TSPCK.

Theoretical framework:

Effective and efficient teaching requires special skills and competence by the teachers. On the basis of this competence lies the knowledge base identified by Shulman (1986) as PCK, where every teacher is expected to competently transform their content knowledge into teachable forms that will positively heighten learner performances. This study is of the view that the development of the broader PCK (of a discipline) begins at a topic level, hence for teachers to be regarded as effective physical science teachers, they should be expected to teach effectively individual topics that make up a physical science discipline. Therefore, PCK is regarded as topic specific (TSPCK). This study draws from the TPK and S consensus model by Gess-Newsome (2015) and the TSPCK model (Mavhunga & Rollnick, 2013) which both reveal the topic specific nature of PCK. The TSPCK model considers five components as important for transforming knowledge; students’ prior knowledge including misconceptions, curricular saliency, what is easy or difficult for students to understand, use of representations including analogies, and conceptual teaching strategies which when used interactively will reveal the topic specific nature of PCK. Reasoning of the topic through these five components reveals one’s PCK that is specific to that particular topic.

Methodology:

This is a qualitative case study of eight physical science pre-service teachers registered for a 1-year full-time PGCE course. This special group of teachers had a content knowledge transformation-based intervention on a topic chemical equilibrium. The intervention used the TSPCK framework of content knowledge transformation (Mavhunga & Rollnick, 2013). Discussions explicitly conferred each component at a time. This framework enables teachers to reason their subject matter knowledge as they plan and teach their topic content. Three of the eight teachers were later followed into teaching. They were observed, each, teaching the same topic of intervention to students from one
Johannesburg high school. The observations were based on “the dynamic nature of equilibrium” and “factors that affect chemical equilibrium position”. All lessons were video-taped and corresponding lesson plans captured. For all the eight pre-service teachers, sets of pre and post-CoRes and TSPCK tests were collected. Tutorial session presentations during the intervention were also captured as data. To understand their espoused TSPCK, all their TSPCK tests were scored using an adopted TSPCK rubric (Mavhunga & Rollnick, 2013). An in-depth analysis of the tests followed in order to explain the scores attained through the rubric. Data from the CoRes and intervention tutorial discussions supplemented the discussion to describe the development across the intervention. Their enacted TSPCK involved identification of episodes/fragments in their teaching where two or more TSPCK components are in interplay (Park & Chen, 2012). These were marked using Miheso and Mavhunga, (2017) rubric for capturing enacted TSPCK. The episodes are pictorially demonstrated through TSPCK Maps and further explained for meaning using the teacher explanations.

Findings and conclusion:

The preliminary findings revealed an improved TSPCK as a result of the intervention. Two important findings were evident at an espoused level; (i) the average individual teachers’ espoused TSPCK improved after the intervention except for one. All pre-service teachers experienced at least an average increase of 1 category jump, from a basic to a developing category after the intervention. (ii) The overall average group score for all components combined increased from 2 to 3, a developing category after the intervention. The group experienced an increase of 1 category jump from a basic to a developing TSPCK proficiency level. The average group scores for all components of content knowledge transformation had improved after the intervention. Three components; LPK, CS and R saw an average increase of 2 category jump from limited to developing after the intervention. The remaining two categories; WD and CTS saw a 1 category jump from basic to developing. Qualitative analysis of these scores indicated a great development in the reasoning ability of the teachers across the intervention. What they could not efficiently do or reason about before the intervention, they could be seen doing with much affluence after the intervention. The development in their reasoning ability reflected in the three teachers that were observed teaching chemical equilibrium. Between three to four components of TSPCK were observed interactively used in most episodes in the explanations that were presented in the classroom teachings. The interactions were mainly between aspects of CS, LPK, R and WD. The component of CS, a very important aspect, was explicitly used throughout the identified episodes as the link provider between other components. It helped to bring clarity to concepts that were scrutinized in the classroom. This implies that the teachers’ enacted TSPCK was mostly at a proficient level as per the rubric by Miheso and Mavhunga, (2017).

References:


THE IMPACT OF A LEARNING STUDY OF THE TOPIC-SPECIFIC PCK OF TEACHERS IN STOICHIOMETRY

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Abstract

The topic of stoichiometry, which deals with the quantitative aspects of chemical reactions, is considered difficult to teach (Gulacar, Overton, Bowmanc, & Fyneweverd, 2013; Kolb, 1978). Students’ poor performance in the topic is also well documented in the literature (Dierks, 1981; Fang, Hart, & Clarke, 2014). In the South African context, students’ poor performance in final exit examinations, particularly on the mole, have sparked concerns over the teaching and learning of the topic, which has, in turn, highlighted the need for professional development (Department of Basic Education, 2014, 2016). In order to improve the teaching of science, practising teachers need to undergo professional development but many of the interventions sanctioned by the Department of Education are short-term, have no theoretical basis and are ineffective (Kriek & Grayson, 2009). Professional Learning Communities, convened and centred around explicit discussions of the transformation of content knowledge for particular topics, therefore offer the potential to improve teachers’ conceptual understanding and understanding of learner errors (Brodie, 2011, 2014; Rollnick & Mavhunga, 2015). Developing practising teachers’ topic-specific PCK through involvement in Professional Learning Communities has been described as a more sustainable and generative method for teacher development (Brodie, 2011), as it can allow teachers to focus on classroom enactment. This paper reports on a study conducted to determine the potential of a Learning Study as a professional development activity to develop experienced teachers’ topic-specific pedagogical content knowledge in stoichiometry.

The study was conducted using a mixed methods research methodology in two distinct phases. In the first phase, the quality of experienced teachers’ topic-specific PCK was determined using instruments to measure teachers’ TSPCK and content knowledge (Author, 2015). Responses to the instrument were used to determine the quality of teachers’ teaching approaches when teaching stoichiometry. This phase of the study highlighted that most teachers teach stoichiometry algorithmically. These results were used to inform the second phase of the study, particularly the focus of the professional development activity. During the second phase of the study, a Professional Learning Community was formed with three teachers selected from those who had completed the instruments in the first phase of the study. These teachers were enrolled in a post-graduate program, with the Professional Learning Community forming part of their own research component. Together with their supervisors as experts, we planned a lesson on the mole, explicitly using the construct of TSPCK in a Learning Study. During the Learning Study, the lesson was critically discussed and improved on over three
cycles. The planning sessions and discussion meeting were video-recorded and the data was coded using the components of TSPCK and teacher knowledge. These discussions formed the basis of determining the development of teachers’ TSPCK.

The improvement in the teachers’ TSPCK was determined through the analysis of pre- and post instruments completed by the three teachers. The pre-test and post-test were subjected to Rasch analysis. This was done by stacking the post-test scores and treating the post-test as though it was written by new people, since the assumption was they were changed through the intervention. The Rasch analysis has shown that after the Learning Study, the three teachers improved their ranking. All three teachers were placed above the median score of the instrument in the second Rasch analysis and their participation in the Learning Study contributed to this improvement. A t-test of the mean scores for the items and persons was conducted to test the assumption that the post-test scores could be treated as new people drawn from the same population of experienced teachers. This assumption was shown to be valid as there was no significant difference between these means for the sample of thirty-one teachers and the sample of thirty-four teachers.

The qualitative data from the PLC meetings was also analysed to gauge the extent to which the specialised knowledge, namely TSPCK, as a component of the TPK&S model, was part of the conversations in the Learning Study. The analysis indicates that the specialised knowledge comprised a substantial portion of the talk units in the PLC activities. Although the teachers’ participation in terms of talk units ranged between thirteen and nineteen percent in comparison to the experts, the engagement still provided opportunities for learning. The quantitative analysis therefore indicates that the teachers’ TSPCK was developed through participation in these discussions in the Learning Study. The study therefore found that the critical engagement of the lessons resulted in an improvement of the teachers’ TSPCK in the topic of stoichiometry.

References


TEACHERS’ PERCEPTION OF THE CONTEXTUAL TEACHING AND LEARNING OF JUNIOR SECONDARY SCHOOL SCIENCE CURRICULUM IN THE MANZINI REGION OF SWAZILAND

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Abstract

Introduction
Contextual teaching situates teaching and learning activities in real-life and vocational contexts to which students can relate, incorporating not only the content, of the “what,” of learning but the importance of the learning. Teachers tend to use abstract examples when teaching science which does not help the learners to see the connection of school science to their everyday lives (Makari, Gervasius and Kasanda, 2006). This study was aimed at investigating teacher’s perception of the contextual teaching and learning (CTL) of junior secondary school science curriculum in Manzini region of Swaziland.

Statement of the Problem
This approach of teaching science in the context of the learner’s everyday life experiences is said to make school science more relevant, meaningful and enjoyable to learners which will then make learners more motivated and interested in doing science. However many learners in Swaziland after passing the Junior Certificate examination tend to drop the sciences due to the fact that they don’t see its relevance to real life situations, further education as well as the world of work. (Kasanda et al, 2005)

Research questions
Four research questions were raised: -

a) To what extent does the JC curriculum in science integrate contextual teaching of science?

b) What types of everyday contexts are used in science classrooms in secondary schools in Swaziland?

c) What are the pedagogical strategies used by teachers in teaching science in contexts in science classrooms?

d) What factors are hindering the effective implementation of contextual teaching and learning of science in secondary schools in Swaziland?

Methodology
The design of the study was descriptive survey. The sample comprised of twelve science teachers from six randomly selected secondary schools in the Manzini region of Swaziland. Three instruments were used to collect data; these were the interview schedules for contextual teaching and learning (ISCTL), questionnaires for contextual teaching and learning (QCTL) and the observation schedule for contextual teaching and learning (OSCTL). Data was analysed using thematic analysis.

Findings and Discussions
The main findings of the study are as follows:
1) The junior secondary school science curriculum syllabus integrates contextualisation to a great extent as the materials used to teach this curriculum are fully contextualised. The starting point is the learner’s existing knowledge, skills, interests and understandings, derived from previous experiences in and outside school. The learner’s books have personalised stories that are used to link scientific concepts to everyday life experiences and over to your sections where learners are given the opportunity to develop their skills in everyday life.
2) Most teachers used episodes referring to everyday words and those referring to personal experience. Not all contexts in the taxonomy suggested by Mayoh and Knutton (1997) were observed in the science lessons.
3) Majority of teachers use the primary pedagogical strategy to teach science more than they use the secondary strategy or the alternative strategy.
4) Time constraints and lack of resources were identified as the major factors hindering the effective implementation of CTL of science by the teachers.

Conclusion
Based on the findings the following conclusion were drawn
1. The junior secondary school science curriculum syllabus integrates contextualisation to a great extent
2. Teachers used episodes referring to everyday words and those referring to personal experience.
3. Teachers rely more on the primary strategy to teach science in junior secondary schools in Swaziland.
4. Time constraint was the major factor hindering teachers from using CTL.

Recommendations
1. Teachers should teach science as stated by the curriculum and make more use of the ‘over to you’ sections to involve learners more in their learning.
2. The science teachers should put more effort in using all the types of context identified by Mayoh and Knutton (1997)
3. Teachers should use both the primary and secondary teaching strategies equally and allow learners to introduce some of the strategies during lessons as the contextual teaching approach advocates that activities in the classroom should be learners based.
4. More periods be allocated to teach science in the junior secondary schools.
References


TEACHERS’ USE OF INFORMAL FORMATIVE ASSESSMENT FOR SCIENTIFIC REASONING IN SENIOR SECONDARY PHYSICAL SCIENCE LESSONS

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Introduction

While Swaziland’s access to education is noteworthy, after achieving a 95.6% access to primary education (UNESCO, 2015), it is less assuring to celebrate this achievement until issues of quality teaching, assessment and learning are considered. Contemporary approaches to learning emphasise the development of knowledge and understanding through talk and inquiry (Sampson & Blanchard, 2012).

For understanding levels to be effective they need regular tracking and use. The appraisal of learning that occurs within the learning process with the purpose of improving learning is referred to as formative assessment (Black & Wiliam, 2009). Formative assessment can either be formal, if planned, or informal, if unplanned (Bell & Cowie, 2001). Informal formative assessment involves instructional dialogues that make learners’ thinking explicit in an unobtrusive way to the point that the learner’s thinking becomes definite and clear for use towards fruitful learning (Ruiz-Primo, 2011). With such a high number of informal assessments in the classroom context, how they are used and how they collectively affect learning cannot be downplayed.

Learning by its nature involves thinking that according to the constructivism theory happens through reflecting with self and through discussions. In Vygotsky’s view the “others” are peers and the teacher (Vygotsky, 1978). The quality of the thinking that occurs within the learning process to a larger extent depends on the degree to which scientific reasoning is supported.

Reasoning as a sense-making undertaking can occur formally when human beings seek understanding within academic domains or informally through everyday life contexts (Bashirah, Ding, Mollohan, & Stammen, 2016). Scientific reasoning is any thinking that seeks to enhance knowledge for achieving understanding (Kuhn, Katz, & Dean, 2004).

Explanations about concepts, events and phenomena can give insight of the nature of reasoning undertaken by learners. The implicit nature of reasoning attaches value to verbal or written explanations since they can be observed objectively due to their explicit and external nature. The study was motivated by the concern that the national performance in Physical Science does not only
perpetually feature below 24% of C grades or better, its average over the last five years ranks below that of each of the other core subjects at this school level (Examination Council of Swaziland, 2016).

The purpose of this study was to assess the extent to which teachers use informal formative assessment to support scientific reasoning in Physical Science classrooms and as such was guided by the questions:

1. How do teachers use informal formative assessment as they teach Physical Science?
2. In what way do teachers’ use of informal formative assessment influence learners’ scientific reasoning strategies?

Methodology

The qualitative inquiry approach with a multiple case study design was used.

Sample and Data Collection

Three Physical Science teachers in the Manzini Region were purposively sampled. The selection was influenced by teachers’ consistently positive performances on SGCSE examinations. Participant lesson observations by both lead and co-researcher were conducted through field notes and audio-recording. Data moderation was achieved through post observation caucus where consensus between the two observers ruled. Pre and post lesson interviews with teachers were also conducted.

Data Analysis

An inductive content analysis approach was engaged. Data were further analysed for the extent to which teachers mediated classroom talk in support for scientific reasoning through Furtak, Harding, Beinbrech, Shavelson, and Shemwell (2008)’s analytical framework.

Findings and discussion

How Teachers Used Informal Formative Assessment

Teachers recognised prior learning through mentioning strengths and areas of improvement from learners’ responses, and explained the misunderstood content in new ways. The practical demonstration with instructional dialogues that T2 used, for instance, led learners to drawing the desired conclusions on their own. This finding is consistent with Kippers, Schildkamp, and Poortman (2016)’s findings that indicated that teachers addressed misconceptions through explaining content in fresh ways.

Informal formative assessment was also used to attend to the teachers’ initial questions. This occurred after learners failed to respond a question. The teachers’ responses involved telling the students the answer or repeating the question at the original or slower pace, and rephrasing the question. According to Ruiz-Primo (2011) rephrasing, clarifying, elaborating, summarising and
repeating a question is a way of offering an explanation of what the question means, and it serves as a helpful scaffolding strategy. While restating the question is helpful Shirley (2009) felt telling learners the answers in response to their failure to answer a question, needs to be avoided as it attracted no learning gain.

The provision of proactive remediation generally refers to the contingent teaching and learning that is motivated by the informal formative assessment outcome. The teachers in this study used oral explanations then made learners do assigned work such as corrections and consolidation classwork. Gamlem and Munthe (2014) uses the term “moments of contingencies” to describe the teachers’ response at this stage of the learning process. Shirley (2009) argues that if this part is done from a rich repertoire of pedagogical strategies chances for improved learning are increased.

The teachers also probed learners reasoning through asking a further question when learners were expecting an evaluative feedback for their attempts. According to Ruiz-Primo and Furtak (2007) the informal formative assessment cycle involves the four stages commonly known as ESRU. By asking a further question the teachers had recognised the learner’s response and used it to pose a further question. It is quite likely the teacher sought a deeper understanding of what the learner had understood and what they had not. In other words, the teachers used informal formative assessment through the ESR-ESR... cycles instead of the single ESRU cycle proposed by Ruiz-Primo and Furtak (2007).

**Ways through Which Teachers Used Informal Formative Assessment to Influence Learners’ Scientific Reasoning Strategies**

The practical demonstration with instructional dialogues that the teacher from the second observed school used, for instance, led learners to drawing the desired conclusions on their own. In a way through allowing the learners to participate in the laboratory demonstration a premise was presented to them. The learners used this premise to project claims as they drew their own conclusions. These conclusions were backed up by the data they observed as the investigation unfolded. Since the teacher initiated the practical demonstration, in Furtak (2008)’s viewing the contribution made by the teacher was at the data-based reasoning level which is a lower level. There were instances where the teacher ended up telling the learners the answer or repeating the question at the original or lower pace, and rephrasing the question. Telling the learners the answer made virtually no contribution to scientific reasoning, yet rephrasing or repeating the question gave the question more contrast. The teacher also used questions or prompts to provide elements of reasoning.

The provision of proactive remediation generally refers to the contingent teaching and learning that is motivated by the formative assessment outcome. The teachers in this study used oral explanations then made learners do assigned work such as correction and consolidation classwork. In this case the teacher provided clarifying statements for the learners. That means the teacher provided the
premise, claim and backing as he attempted to prompt learners for elements of reasoning. The teacher from the third observed school responded to learner questions with why or how questions. These questions demanded that learners elaborate on or justify their claims. This approach to learning was classified as adding value to learners’ reasoning (Furtak, Hardy, Beinbrech, Shavelson, & Shemwell, 2008).

CONCLUSION AND RECOMMENDATION

All in all, teachers used informal formative assessment in line with standard practices though they often resorted to telling learners answers to seemingly demanding questions, something that had a weaker bearing on scientific reasoning. In-service workshops focusing on probing skills are recommended for these teachers.

References


THE RELATIONSHIP BETWEEN TEACHERS’ PEDAGOGICAL CONTENT KNOWLEDGE (PCK) AND STUDENT LEARNING IN ELECTROSTATICS

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The South African education system has been described as ‘struggling’ by the Centre for Development and Enterprise (CDE, 2015), especially in the production of scientific literate learners. Several reports have shown that South African learners perform poorly in local and international assessments in physics, particularly in the topic of electrostatics. Although many factors affect learners’ performance, teachers are regarded as the central figure that can make or break effective learning (Akiba, LeTendre & Scribner, 2007, CDE, 2015). Unfortunately, there is a shortage of qualified science teachers in South Africa and the production of new teachers in teacher education institutions is low (CDE, 2015). The government has therefore established teaching bursaries to increase enrolments in teacher education institutions. The institutions have also been urged by the CDE to strengthen their training by emphasising content knowledge, pedagogical content knowledge (PCK) and a strong teaching practice component in real classroom settings. PCK refers to the transformation of raw content into teachable forms and is regarded as the knowledge base that shapes effective teaching (Cochran, DeRuiter & King, 1991). This study investigates the practices of both pre-service and in-service teachers in terms of PCK, particularly its relation to student learning. Several reports in literature have indicated that PCK develops through teaching experience and that pre-service teachers predominantly exhibit ‘naturally limited PCK’ (Kind, 2009, p. 182). Those reports necessitated the inclusion of experienced teachers in this study to have a wide range of PCK bases and to investigate their relation to student learning. The sample will therefore consist of two pre-service and two experienced teachers respectively, as well as the learners that they will be teaching. The following question will guide this study:

• What is the relationship between teachers’ pedagogical content knowledge (PCK) and student learning in electrostatics?

This study will adopt a mixed method (QUAL-quan) research approach using a case study research design (Maree, 2010). Teachers’ PCK will be explored qualitatively using a content representation (CoRe) tool (Loughran, Mulhall & Berry, 2004), classroom observations and interviews. However, it will be assigned a quantitative score that represents its quality on a four point scale. Evidence of student learning will be explored quantitatively using a validated performance test. The Topic Specific PCK model by Mavhunga (2012) will be adopted as the framework that will guide this study. According to the model, a specific topic is transformed into a teachable form through five components namely: learners’ prior knowledge including misconceptions, curricular saliency, what is difficult to teach,
representations including analogies and conceptual teaching strategies. However, it is argued that a precise investigation of the relationship, or lack thereof, between teachers’ PCK and student learning requires explicit focus on concepts within a topic. Although the CoRe tool and the TSPCK model were developed for specific topics, they will be used to explore teachers’ PCK about specific concepts within the topic of electrostatics. The performance of the learners will also be concept based such that it can be related to the PCK of the teachers about the same concepts.

References


Abstract

Physics is characterized by having a lot of formulas that in general are obtained by using deduction or induction methods. The students face difficulties in understanding physics to some extent due to the lack of usage of different laws and principia’s to get a general mathematical expression when it comes to solving problems and not exercises.

Due to the development of technologies and modernization of teachings means, like data show, interactive boards, advanced simulation software’s, the physics teachers in Mozambique get their lessons easily done when using the modern teaching means.

As physics teacher/lecturer at Pedagogical University of Mozambique, the author used two different methods of teaching Mechanics subject. In the first 2 weeks, the lessons were powerpoint based and in the next 2 weeks, the lessons were taught using the traditional method: board + dictation of the contents.

In the end of each 2 weeks of lessons, the students were evaluated through solving problems on which it was demanded for them to show all the steps of their resolution.

The findings were that, in the first assessment, after the PowerPoint lessons, 73% of the students failed. Nevertheless, in the second assessment, the percentage of negative marks was 31%.

Based on these results, the author concluded that, using the traditional approach in physics lessons, the students are more likely to understand and follow the steps of resolution or teaching and this helps them to easily learn and use the knowledge to solve physics problems and other day by day problems.

Keywords: PowerPoint based lessons; board-based lessons, physics.
Introduction

The progression in September 2015 at the UNESCO Sustainable Development Summit from MDG2 (to achieve universal primary education) to UNESCO 2030 Agenda for Sustainable Development SDG 4 (to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all) is quite significant for education. I believe that for the Southern African context it creates a new dynamic that will impact science education in interesting and challenging ways in the region. While the MDG2 focus on primary science was critical for access and equitable provision of education at the most basic level, the region was still quite strongly focused on secondary education particularly on matters of throughput numbers at the exit grades. The SDG4 objective of education for all has the potential to now shift both political and economic focus (back) to the quality of secondary level education. Science as one of the flagship subjects will be in the spotlight. As a biologist myself I am curious to track biology education going forward to see how we (as a region) will work towards achieving SDG4. I decided to start by looking at Biology research reporting at SAARMSTE conferences. I address the question, how is Biology education research represented and reported at SAARMSTE conferences? I have so far only looked at three SAARMSTE conferences 2016-2018 as they are in the period following the UNESCO2030 Agenda. However, I intend to extend the data analysis to cover the last decade so as to include any research pertaining to MDG2. I believe this will begin to generate baseline information on the status of Biology education and Biology Education research in the region.

Literature and framework

I start by presenting the state of Biology (Life Sciences) in South Africa as reported in the Department of Education’s 2017 Diagnostic report (Table 1).

From the figures presented in Table 1 it is clear that many more learners sit the Life Sciences examination than do the Physical Sciences. Although for the past four years the ratio achieving above 40%, the official pass mark is higher in LS than in PS it has been below the 50% mark only exceeding it for the first time in 2017. Clearly there is a lot that we still do not understand about the teaching and learning of Biology in the South African education context. Thus, the need not just for the research on Biology education and
Table 1. The number of learners who wrote matric exams and overall achievement rates in Life Sciences and Physical Sciences

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<th>Year</th>
<th>No Wrote</th>
<th>No. achieved at 40% and above</th>
<th>% achieved at 40% and above</th>
<th>No Wrote</th>
<th>No. achieved at 40% and above</th>
<th>% achieved at 40% and above</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>284 298</td>
<td>139 109</td>
<td>48.9</td>
<td>167 997</td>
<td>62 032</td>
<td>36.9</td>
</tr>
<tr>
<td>2015</td>
<td>348 076</td>
<td>160 204</td>
<td>46.0</td>
<td>193 189</td>
<td>69 699</td>
<td>36.1</td>
</tr>
<tr>
<td>2016</td>
<td>347 813</td>
<td>157 224</td>
<td>45.2</td>
<td>192 710</td>
<td>76 068</td>
<td>39.5</td>
</tr>
<tr>
<td>2017</td>
<td>318 474</td>
<td>166 071</td>
<td>52.1</td>
<td>179 561</td>
<td>75 736</td>
<td>42.2</td>
</tr>
</tbody>
</table>

Adapted from Diagnostic report Part 2 Pages 116 and 175 (DBE 2017)

There are several different ways to look at Biology Education Research (BER). Reiss (2016) presents a Venn diagram that sits BER at the intersection of three overlapping domains; biology, education and research. Thus, such work should have features of all three domains with varying emphasis depending on the objectives. Other ways of viewing BER have been suggested. For instance, McComas and colleagues suggest working with “emerging Grand Challenges in Biology Education” which include topics such as teacher education, the role of language, socio-cultural issues, socio-scientific considerations and other notions as they relate to what they call “biology didactics” (McComas, Reiss, Lee, Olander, Clément, Boerwinkel, Jan Waarlo 2018). I drew from these theories in deciding what data to collect and how to collect and analyse the data.

Methodology

This paper is partly a position paper and partly a research review paper using Biology education research papers at SAARMSTE as the empirical data. One of the requirements in a review is to determine criteria for inclusion or exclusion of papers in the review as well as delineation of period of the review. For the preliminary stage of the review I look at research reported at SAARMSTE 2016, 2017 and 2018 in line with the duration of the UNESCO 2030 Agenda. In terms of selection criteria for inclusion or exclusion of papers in the review I look at research reporting findings about Biology education research as defined by Reiss (2016). I have excluded research on general science education issues not directly linked to Biology or Biology Education. I included curriculum and textbook related research which tends to be more easily identifiable and classifiable as Biology related. Here are some examples of research that was excluded:

- Work conducted in Biology classrooms but reporting general science issues
- Research conducted by Biologists but not reporting Biology findings (just science or just pedagogy);
- IKS work linking only implicitly to biology – e.g. eliciting elders IK but not yet transferred to CR even though it will be later.
- Visits to Biology science centres - papers reporting about the visit and not the biology – e.g. preparation, emotions, science interest, entertainment vs learning, etc.
- Work in NS classrooms which is about all the sciences and does not explicitly refer to Biology
- Environmental education research – although it includes Biology (Life Sciences) but with a specific focus on the environment and not Biology content per se.

**Data analysis and results:**

*Table 1. Number of science presentations at SAARMSTE in 2016-2018*

<table>
<thead>
<tr>
<th>Year</th>
<th>Long papers</th>
<th>Symposia</th>
<th>Short papers + snapshots</th>
<th>Round tables</th>
<th>Biology Totals</th>
<th>Total Science papers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2018</td>
<td>7 (0)*</td>
<td>3 (1?)</td>
<td>84 (13)</td>
<td>0</td>
<td>14 (14.9%)</td>
</tr>
<tr>
<td>2</td>
<td>2017</td>
<td>13 (1)</td>
<td>1 (1)</td>
<td>92 (8)</td>
<td>2 (1?)</td>
<td>11 (10%)</td>
</tr>
<tr>
<td>3</td>
<td>2016</td>
<td>12 (0)</td>
<td>2 (0)</td>
<td>82 (15)</td>
<td>4 (0)</td>
<td>15 (15%)</td>
</tr>
</tbody>
</table>

*Number of Biology papers in brackets*

The number of Biology papers remains relatively low at SAARMSTE, ranging between 10 and 15% in the last three years. Considering that Biology is one of three sciences it could be expected that a third of the science papers would be Biology papers.

**Qualitative data from SAARMSTE proceedings**

The biology papers are categorised according to McComas et al (2018), emerging Grand Challenges in Biology Education: teacher education, the role of language, socio-cultural issues, socio-scientific issues. In McComas classification the category “teacher education” seems to include most of what is presented at the SAARMSTE conference by virtue of its being an “education” conference. I therefore adjusted this category to only include papers specific to the Biology teacher education context and then classified the rest according to themes emerging within the data, e.g. pedagogy, laboratory work, the teaching and/or learning of specific topics (see Table 2).

*Table 2. Categories of Biology education research*

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of papers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher education</td>
<td>8</td>
</tr>
<tr>
<td>The role of language</td>
<td>1</td>
</tr>
<tr>
<td>Socio-cultural issues</td>
<td>6</td>
</tr>
<tr>
<td>Socio-scientific considerations</td>
<td>4</td>
</tr>
<tr>
<td>Laboratory work</td>
<td>1</td>
</tr>
<tr>
<td>Pedagogy</td>
<td>15</td>
</tr>
<tr>
<td>Specific topics</td>
<td>4</td>
</tr>
<tr>
<td>Teaching practice</td>
<td>1</td>
</tr>
<tr>
<td>TOTAL</td>
<td>41</td>
</tr>
</tbody>
</table>

It seems that most Biology education research reported at SAARMSTE is in the pedagogy of biology and in teacher education matters. This is not surprising considering the curriculum change context
within which this research is taking place, particularly the emphasis on learner-centered pedagogies. I will discuss these trends further at the SAARMSTE conference presentation.

Discussion

I invite the SAARMSTE audience to consider with me and discuss the implications for future Biology education research and future reporting at SAARMSTE. I also discuss other global initiatives in Biology education research such as:

- The European Researchers in Didactics of Biology (ERIDOB) since 1996 with a focus on Biology, Biology research, Biology education research.
- The Society for the Advancement of Biology Education Research (SABER) since 2011 with an undergraduate Biology emphasis.

References


IMPACT OF THE USE OF MUSIC AND GAMES IN THE PEDAGOGICAL PERFORMANCE OF BIOLOGY STUDENTS OF SECONDARY SCHOOLS OF MATOLA AND MASSINGA IN MOZAMBIQUE

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Abstract
Our study aims to evaluate the impact of the use of music and games in the pedagogical process of teaching of Biology in general secondary education of the Public Schools in Maputo and Inhambane provinces. The study was carried out in two secondary schools of the first cycle, namely Massinga Secondary School in the province of Inhambane and Matola Secondary School in the province of Maputo, involving 107 students from the 9th and 10th grades. For the data collection, questionnaires with closed questions and simulated classes using music and playing cards were used, considering groups with music or game and classes without music or without game, at the end of the learning the students were evaluated their pedagogical performance. For the statistical analysis of the data, the statistical package SPSS version 24.0 was used, observing the 95% confidence level. The results of the learning showed that the students who studied using the game of cards presented better pedagogical performance than those who studied with music. These results show that the use of games in education can constitute better technique of didactic accomplishment of the classes of biology when compared to music.

Keywords: games, music, teaching of biology.

Introduction

Music and games are means of mediation of contents of difficult learning that can allow to improve the performance of the student of the natural sciences. These means of mediation of science teaching in primary and secondary education seek to avoid the excessive use of contents those sometimes difficult to assimilate. Currently, the science classes tend to be more traditional prevailing the memorization of contents and leaving the association between content and everyday life as it was at the XXI century in which Didactics was synonymous of a practical pedagogy in which teaching methods and techniques were intended to help teachers teach a particular subject.

It is therefore necessary that all school actors involved in learning are aware and able to this new challenge. However, it is known that this is not the only problem and consequent challenge that we find in the reality of Mozambican education. According to Pinto, (2009), there are problems of poor
quality of teaching, school dropout, political management problems, structure of the school and family environment, among other possible causes.

It is in this context that our study aims to evaluate the impact of the use of music and the game in the pedagogical use of Biology students of the general secondary education of the Public Schools of Maputo and Inhambane. The study is relevant to the extent that it can contribute to the massification of the use of alternative pedagogical techniques that favor the construction of knowledge to the student in a playful way, thus adapting the teaching and learning process to current challenges.

Methodologies

The study was carried out in two secondary schools of the first cycle, namely Massinga Secondary School in Massinga district, Inhambane province and Matola Secondary School in Maputo province, involving 107 students.

Concerning to the data collection, questionnaire, interview, survey or written tests were used, as it was applicable to the most diverse segments of the study population, and because it enabled the obtaining of quantifiable data. In addition, the observation method was used to collect information about student behavior during the teaching and learning process of students. Procedures for writing the songs, the lyrics of the songs were based on the contents of the student's book, later they were rehearsed and composed in pedagogical workshops of the Pedagogical University of Mozambique and later recorded in the form of several musical styles in a home studio of Maputo city. The Deck game on "cell study" was elaborated based on the existing literature on specific contents of the Cytology.

In each school the research was carried out with two classes of 9th grade students for the playing cards on the content "cell study" while the music with the content on "environmental pollution" was carried out with two classes of students of the 10th class, in each case (music or game) a class had the classes consolidated using music or game to another class submitted to a traditional class (without music or game). The application of the music in the class was based on the methodology developed by Oliveira et al., (2011), but modified.

For the student’s assessment, after the teacher's presentation and consolidation of the contents of the lesson using music or games, the students were evaluated through written tests, previously elaborated, comparing the income obtained by the students of the two groups of classes that learned with music or game and classes that learned without music or game, to ascertain the extent of the contribution of music in the students' learning process.

For the statistical analysis of the data, the statistical package SPSS (Statistical Package for Social Sciences) version 24.0 was used, observing the 95% confidence level. The results were presented in averages of the frequencies and percentage of averages.
Results

Possibilities of using games and music in biology classes
Results of student surveys on whether or not their teachers can use games or music in their classrooms, shows that about 61.8% of the students in the two schools studied said that their teachers did not use music as a didactic medium and 51.0% stated that their teachers did not use music as a didactic medium.

Pedagogical performance of students who study with music or games
The pedagogical performance is shown in graphs A, B (figure 1), C and D (figure 2). In these figures can be observed that the students who studied with music showed better pedagogical achievement (50.47%) in the good scale and (13, 08%) in the very good scale when compared to (23.36%) on the good scale and (9.34%) on the very good scale (figure 2, A and B). While the students who studied using game of cards presented better pedagogical performance when compared to those who studied with music with (57.06%) in the scale of sufficient use up to good and (30.84%) in the scale of good, (29.25%) in the good and (11.21%) in the very good scale (figure 4, C and D).

Discussion
The music, still in a timid manner, has been used as a tool to teach scientific content, an alternative little applied in Mozambican schools. However, one of the requirements of Biology teaching is articulated with the development of critical curiosity, unsatisfied with applied research and teaching methods, but this dissatisfaction becomes important when it satisfies the pedagogical sense of students’ biology classes when they leave the know-how to know how to think and know, as a way of stimulating educational research (Barreira and Moreira, 2004).

However, the results obtained in our study regarding the pedagogical achievement of the students who studied with music can be analyzed considering the level of materialization of the objectives and competences set for the classes. In addition, the fact that we have demonstrated that despite the music provides good pedagogical use, although less than the game is still more interesting to our study and can promote many inquiries (Libâneo, 2002). Thus, games and music are linked to emotions, it is through them that men also communicate or demonstrate their socialization potential, being that it constitutes a form of language. The human being who includes the music in his life, somehow, has the collaboration of the same to develop his senses, his emotions and, consequently, the harmony of living (Silva et al., 2015).

**Conclusion**

Our study suggests that although music provides better pedagogical performance, games may be a better alternative, because in our study we found a greater (Good and very good) pedagogical achievement performance in students who studied using game. This study feeds the perspective of commitment to the need to train students capable of building their Biological knowledge and become citizens not only with the know-how but also to face the phenomena and natural processes resulting from social dynamics using innovative methods of teaching, as in the case of music and games. Lastly, possible to transform traditional and technicist didactics to the reflective, investigative and inclusive didactics.

**References**


TEACHING FOR CONCEPTUAL UNDERSTANDING: THE USE OF THE TRIANGLE OF LEVELS OF THOUGHT
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Abstract
An explanatory case study inquiry was undertaken to investigate five teachers teaching the topic electrolytic cells and its fundamental concepts from Grade 10 to 12. The teachers were observed teaching three lessons on the topic and were interviewed after teaching. The data was analysed using Scott’s scales of representations (macroscopic, sub-microscopic and symbolic) and Johnstone’s triangle of levels of thought. The analysis was meant to identify teacher use of macroscopic, sub-microscopic and symbolic levels in the teaching and learning process. Findings indicate that the sub-microscopic level was superficially used by the participants, which compromised conceptual understanding of scientific concepts. Use of the triangle of level of thought by teachers ranged from the use of one to the use of all sides of the triangle of levels. Teachers cited lack of adequate resources, congested curriculum and inadequate training as limiting factors in fully utilising the levels of representations. Hence, there is a need for professional development of in-service teachers with the pedagogical knowledge that foster conceptual understanding.

Introduction
The study focuses on the teaching of electrolytic cells and its fundamental concepts for conceptual understanding. The topic electrolytic cells is known to be abstract and problematic for learners to comprehend (Mumba, Rollnick, & White, 2002). In its 2014 diagnostic report the South African Department of Education recorded limited conceptual understanding of the concept of electrolytic cells by Grade 12 learners during the final examination (Department of Education, 2014). Furthermore, in one of the South African universities some chemistry first-year students were found to have an inadequate scientific understanding of fundamental chemical concepts (Davidowitz, Chittleborough, & Murray, 2010). Meanwhile other research found that in-service teachers lack the skills to organise learning approaches that foster conceptual understanding (Mestry & Ndlovu, 2014). Conceptual understanding is achievable in an interactive social environments where a learner is a participatory subject who attains knowledge through direct involvement with more knowledgeable members of the society (Vygotsky, 1962). Hence, this study mainly focusses on how the teacher unpacks the subject matter of electrolytic cells and its fundamental concepts into the content that learners comprehend meaningfully. To what extent do teachers use the scales of representation; the macroscopic, sub-microscopic and symbolic in their teaching of the topic electrolytic cells and its underlying concepts in Grade 10 to 12.
Literature review

Scott, Mortimer, and Ametller (2011) describe the three levels/scales of explanation as follows: macroscopic representation is the visible and tangible Science phenomena; microscopic representation is the particulate level of matter that is made up of invisible entities such as atoms, molecules and ions; symbolic representation comprises of an array of pictorial representations of molecules, ions, compounds and other species. Scott et al. (2011) found out that learners find it difficult moving between these different levels of representation. Gabel (1993) in her study on teaching about the particulate nature of matter using symbolic, macroscopic, and microscopic found out that learners who were taught in more than one level of explanation achieved higher scores than those who received one level of scale of explanation. Johnstone (1991) argues that natural sciences could be taught using the triangle of levels of thought which places macroscopic, sub-microscopic and symbolic at the corners of a triangle. It is vital to integrate these levels in order to teach for conceptual understanding. That is, teachers and learners should be able to shift among the three levels or scales of representation in order to gain a good understanding of chemical concepts (Johnstone, 2000). Hence, teachers should be able to organise learning material in such a manner that learners can make links between the content of science and each level (Scott et al., 2011).

Methodology

Five Grade 10 to 12 Physical Science teachers were invited to participate in the study. Table 1 below shows the grades and topics each teacher taught. The five teachers were observed teaching three lessons each, in their respective grades: Grade 10 (Reactions in aqueous solution); Grade 11 (Redox reactions), and Grade 12 (Electrolytic cells). The main thrust of lesson observations was to determine whether teachers made use of the triangle of the level of thought in their teaching. Each teacher was then interviewed after the three lessons mainly to get clarity on some of the observations made during the lesson presentations. The data was analysed using the approach of moving between different scales and levels of explanation adopted from pedagogical link-making to promote knowledge by (Scott et al., 2011).

Findings and discussions

The use of each scale of explanation by each teacher was analysed, by identifying scenarios where teachers used macroscopic, sub-microscopic and symbolic scales of representations in their teaching. Each teacher’s use of the three levels was tallied as shown in the frequency table, Table 1.
The table above shows that the symbolic level was the most frequently used representation at 64% followed by the macroscopic scale (27%). The sub-microscopic level of representation was used the least at 7%. The sub-microscopic level was the least used scale of representation in the teaching of electrolytic cells and its fundamental concepts. Al-Balushi and Al-Hajri (2014) argue that shallow experience with the theoretical level leads learners to miss the opportunity to meaningfully apprehend the interrelatedness of the macroscopic, sub-microscopic and symbolic scales of elucidation. Although learner understanding of the topics was not measured, failure by teachers to draw adequately on the sub-microscopic level compromises the potential for conceptual understanding of the scientific phenomena.

Further analysis showed that the macroscopic and symbolic scales of representations was the most used combination to explain concepts by teachers. The combination of all three levels macroscopic, symbolic and sub-microscopic was the least used to explain scientific phenomena only two teachers implemented it, Mr Johannes, and Mr Masutha. Results from teacher interview showed that syllabus congestion and inadequate training in the use of the triangle of levels of thought contributed to the shallow use of sub-microscopic level of representation.

Conclusion

Two main findings were vivid in this study. Firstly, teachers overemphasise the use of symbolic level of representation more than the macroscopic and sub-microscopic levels of representations. Secondly, teachers hardly explained the scientific concepts using the three levels of representations simultaneously.
References


THE QUALITY OF GRADE 12 PHYSICAL SCIENCE TEACHERS’ TSPCK CONTENT TRANSFORMATION ON THE TOPIC OF ELECTROCHEMISTRY.
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mfumai@yahoo.com

Introduction

One of the topics causing difficulties in the South African physical science curriculum is electrochemistry. In the South African National Senior Certificate Examinations, electrochemistry counts 20% of the total chemistry paper and students find it difficult and therefore do not do well in this section. An obvious course of action to improve student performance is to improve the quality of the teaching of this topic. Of the many teacher knowledge bases associated with quality science teaching, strong PCK which comes with experience is thought to be paramount. PCK is specialised teacher knowledge which enables transformation of content knowledge (CK) into teachable form. Teacher knowledge of topics may vary and because PCK is a complex concept, it has been conceptualized as Topic Specific Pedagogical Content Knowledge (TSPCK) first proposed by (Mavhunga & Rollnick, 2013). When TSPCK is measured and established it can be standardized (canonized) as a definition of quality for Physical Science teachers in that topic. An important precursor of TSPCK is the relevant CK in the topic.

Purpose of Study and Research Questions

The aim of this study is to explore the quality of Mpumalanga physical science teachers’ topic specific pedagogical content knowledge in the topic of electrochemistry.
To respond to the research topic, the question is:
What is the quality of the Mpumalanga Province Grade 12 Physical Science Teachers’ CK and TSPCK on the topic of electrochemistry?

Literature Review

Conceptual Framework: Topic Specific Pedagogical Content Knowledge
In this study the aim is to determine the knowledge possessed by teachers for teaching the topic of electrochemistry. Hence Mavhunga and Rollnick’s (2013) model of TSPCK was employed. These authors conceptualise TSPCK as being composed of five components which together embody the construct. The five components are Students’ Prior Knowledge (SPK), Curricular saliency (CSA), What is difficult to teach (WDT), Representations (REP), Conceptual teaching strategies (CTS).
**Methods**

The research uses Mixed Methods and its main focus is on collecting, analysing, and mixing quantitative and qualitative data in a single study (Creswell, et al., 2011). This is a single study where TSPCK and CK instruments are used to determine the quality of physical science teachers. The study made use of two previously validated instruments to measure CK and TSPCK in electrochemistry Ndlovu (2014). The TSPCK instrument allowed for both qualitative and quantitative data so the study employed a mixed methods approach.

The sample population used consisted of 37 respondents comprising of a convenience sample of 22 Local Males (LM), 3 Local Females (LF), 10 Expatriate Males (EM) and 2 Expatriate Females (EF). The CK instrument was used to uncover the teachers’ CK in electrochemistry, as well as some of their misunderstandings of the topic that could perpetuate misconceptions or errors in students (Rollnick & Mavhunga, 2014). The TSPCK Instrument was structured around the five components elucidated above.

A TSPCK rubric was used to code the teachers’ responses on a scale of Limited (1), Basic (2), Developing (3) and Exemplary (4). An inter-rater reliability of 80% was established by obtaining independent scores on a sample of scripts by 3 experts. The CK scores were obtained using a memo. The generated scores were compiled on Excel and analysed, using the Rasch statistical model using the RUMM 2030 programme. Rasch analysis converts the ordinal scales (1 to 4) obtained to linear numerical scales (Bond & Fox, 2001). The data was also subjected to qualitative analysis of teachers’ verbal responses.

**Results and Discussion**

Some findings are provided below: Regarding the quality of scores:

- The finding of fit of the CK and TSPCK combined data to the Rasch model was excellent meaning the construct being measured was valid.
- The Rasch model displays person and item scores anchored on an item average of 0. The Person mean was 0.167 showing that the teacher scores were well matched to the item average though their standard deviation was wider than that of the items. The obtained reliability was good at 0.9.

The second finding is the determination of the order of location of physical science teachers’ quality of topic specific pedagogical content knowledge in electrochemistry. The TSPCK quality varies from location +1.411 being the highest TSPCK quality to the least at -1.916 all compared to anchored item mean of 0.

Thirdly with regard to TSPCK and CK separately:
• A study of the TSPCK data alone showed an excellent fit but this time the teacher mean was below the item mean, meaning that the TSPCK items were more difficult for the teachers than the CK items.

• Analysis of the CK items alone showed a reasonable match between the items and the teachers.

The fourth finding depicts the Person – Item relationship in TSPCK. Two items presented a challenge for all the teachers, one related to the component Curricular Saliency – to make a map or diagram on how 3 major big ideas of the topic link to subordinate concepts - and the other to Conceptual Teaching strategies – to explain how one would assist learners to move from misconceptions to correct answers explaining how their errors are - were the most challenging.

Discussion on the TSPCK Quality of Content Transformation:

Below we provide some exemplars of responses from the top ten and bottom ten teachers:

In the category of student prior knowledge, the teachers were asked to respond to a statement from a learner as follows:

“The electrons flow through the salt bridge to keep the galvanic cell neutral”

Below are two contrasting responses from a high scoring and low scoring teacher (Fumi located at +1,411 and Maka at -1,696). Fumi adequately identifies misconceptions and expands and rephrases explanations correctly and in this case confronts misconceptions with accurate understanding whilst Maka identifies misconception he has no recommendation on how to confront it.

One of the best reasons for using the TSPCK model is that it assesses the physical science teacher quality of knowing what is difficult or easy about the topic. In this category, the teachers were asked as to what concepts (selected form a list) they find difficult or easy to teach in electrochemistry. Koko (+1,317) identifies specific concepts with reasons like teaching of strong and weak oxidizing and reducing agents to explain residue deposits in purification. He further provides reasons linking to specific gate keeping concepts like the movement of ion in solution and electrons in external circuit – this links to the need for strong conceptual teaching strategies and Tutu (-1,916) only managed to identify a broad topic of particle flow without specifying actual sub-concepts which are problematic.

As stated above the conceptual teaching strategy component was difficult for most teachers. In this task teachers were asked to critique a series of incorrect electrolysis equations. A particularly strong response was shown by Hola who was located at +1,317 was the only one who showed exceptional performance in this category. He shows overall excellent strategy. He considers student prior knowledge, confronts misconceptions and ability to sequence important conceptual aspects thus integrating other TSPCK components.
Conclusions

The results from this study provided an understanding of some of the measures involved to determine the quality of Science Teaching. More teacher development should take place in this topic, for the fact that electrochemistry is central part topic in many chemistry curricula at school and university level (Taber, 2013). Again, it is argued that poor performance in chemistry is been attributed to poor teacher preparation and thus poor understanding of content in chemistry concepts by teachers (Rollnick & Mavhunga, 2014).

TSPCK simply allows a lens in the measurement of those latent characteristics that are teacher’s expression of science teaching knowledge and integration of multiple factors in pedagogical reasoning – students prior knowledge, curricular saliency, and conceptual teaching strategies).

References


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Abstract

Epistemological therapy entails the selection of epistemic styles teachers engage to ensure learners in disadvantaged communities construct knowledge using appropriate examples from their indigenous knowledge. This study focused on the epistemic therapeutic nature of indigenous knowledge. To accomplish answering the research question, What epistemic therapeutic role can IK bring to Eurocentric technological infrastructure deprived schools?, the study used observations, interviews and cultural analysis as instruments to understand the therapeutic nature of indigenous knowledge. The revelation was use of models, patterns and case studies anchored on indigenous knowledge teachers used reflects that metaphorism epistemic style is activated and acts as an epistemological therapy.

Background of the study

The study focused on how science teachers can therapeutically engage learners during science teaching through the use of an indigenous knowledge epistemic style. Epistemic styles according to Dickerson (2010) are constructs which synchronously invoke a valid truth criterion. Three epistemic styles which lessen adversaries in learners needing epistemic therapy exist. These three epistemic styles are, namely, rationalism, empiricism, and metaphorism. Dickerson (2010) labels these epistemic styles as: individualizing, systems and poststructural/social constructionist. Earlier, Pepper (1942) suggests four epistemic styles and like others considers them as ways of seeing the world and organizing experiences and classified into formism, mechanism, contextualism and organicism.

Rationalism asserts that thought has superiority over the senses with regards to epistemology (Dickerson, 2010). This assertion is shared with individualizing and formism. Empiricism, systems and mechanism maintain that sensory experience is the main way of knowing accurately (Dickerson, 2010). Finally, the metaphorism perspective sees knowledge as flexible, embedded within individuals, socially constructed and symbolical (Dickerson, 2010). This perspective is shared by poststructuralists/social constructionists and contextualists. Organicists value multiplicity and one’s own experience and prior knowledge (Benoit, 2012). Although the study used metaphorism perspective to explore: “What epistemic therapeutic role IK can bring to Eurocentric technological infrastructure deprived schools?” other epistemic styles were also valued. The intention was to have the contextual aspects embraced instead of fumigating IK reflecting science (Odora-Hoppers, 2001).
To explore this, indigenous knowledge system (IK) linked to epistemic therapy where cultural artefacts play the role of technological infrastructure were analysed and used as models or case study construction (Mukwambo, 2017). The aim was to find how can an IK linked epistemic style be used as an epistemic therapy in science teaching in Eurocentric technological infrastructure deprived schools. The belief is that the epistemological approach as a function depends on the three epistemic styles. However, in the case of learners in Eurocentric technological infrastructure deprived schools, the rationalism and empiricism perspective are dormant while the social constructionist perspective is active. This led to the consideration of the social constructionism as a theoretical framework.

**Theoretical framework and literature**

Social constructivism views knowledge as socially constructed not created (Andrew, 2012). In social discourse, indigenous communities use observations to accurately reflect on the world. They construct metaphors, analogies and similes using language (Dickerson, 2010) and use these to come up with cultural artefacts/explanations embedded with science knowledge that can be used in epistemic therapy in science teaching.

Metaphorism epistemic style uses a metaphor, an analogy or simile to construct knowledge. However, a metaphor and a simile are more general and difficult. Difficulties with the interpretation include: (i) too many possible interpretations; (ii) some are too ambiguous and abstract to be interpreted; and (iii) they can be interpreted differently by different researchers (Xu, 2010; Mouraz, Pereiro & Monteiro, 2013). A metaphor reflects beliefs; beliefs focus people’s perceptions as they socially and historically construct knowledge (Yero, 2002). Like an analogy, a metaphor is used to transfer features of knowledge in base domain to features in target domain (Orgil, 2013). Pellegrino and Hilton (2012) refer to this as transferring knowledge from one base domain to the required target domain. The features above allow relating knowledge already known to the intended knowledge; this allows the use of metamorphism epistemic style to recognize that metaphors, analogy and even similes constitute human cognition (Snævarr, 2010). The mind finds a match for those features in prior experience with those in the perceived knowledge. The essence of metaphor, according to Xu (2013) is the understanding and experiencing of one kind of thing in terms of another. For a learner in a Eurocentric technological infrastructure deprived school, cross-domain mapping in the conceptual system is attained when the IKS depicting the environment is used. “A teacher who believes students learn through active social interaction with their environment will perceive better levels of classroom talk once the focus is on using metaphors and analogy constructed culturally (Sabatin, 2013).

The teacher may unconsciously find a match in situations where productive activity is taking place. For example, hide curing using mopane ashes or explanations of how an ant-eater (aardvark) survives in a hole believed to be lacking oxygen are cases in point (Mukwambo, 2017). Saponification and pressure concepts as cultural practices can be taught using knowledge transfer. Oxygen supply in an
ant eater habitat is dependent on atmospheric pressure variation yet indigenous communities have a lot of metaphors or analogies. In the case of hide curing, ideas related to saponification emerged. The use of metaphors is also influenced by the situation in which those metaphors are used; different situations may bring about different metaphors in the same teacher and different teachers in the same situation. This is also supported by the idea that metaphorism embraces multiplicity (Benoit, 2012).

**Methodology**

The study analysed cultural practices to find how the science in them can be used in epistemic therapy in science teaching. Observation valued in metaphorism was embraced (Orgil, 2013). Interviews elucidated the views of three teacher participants and also assisted with data triangulation. The science ideas found during analysis of cultural practices such as hide curing using ashes and explanation on how an ant eater survives in a hole were used by the science teachers to come up with case studies, models and patterns. While teaching, the researchers observed how the class was conducted. That allowed some further data to emerge which was then used in the findings.

**Findings**

Findings responding to the research question: “How can an IK linked epistemic style be used as an epistemic therapy in science teaching practices in Eurocentric technological infrastructure deprived schools?”, three teachers interviewed responded as follows:

- **Teacher 1:** Use of case studies anchored on IK makes teaching and learning a healthy encounter.
- **Teacher 2:** Models reflecting IK I engaged fixed the challenges learners encounter.
- **Teacher 3:** Use of models or case studies anchored on IK reconciles Eurocentric science and IK.

These interview responses pointed the need to use epistemological views in which models, patterns and case studies based on prior knowledge of learners (Benoit, 2012; Mukwambo, 2017). Also, the epistemic therapeutical nature is revealed from the words teachers used to respond; healthy, fix and reconcile, these have healing connotation. Observation further supported. Science knowledge analysed in cultural practices was found to be constructed during social intercourse through the use of language as supported in social constructionism (Andrew, 2012).

**Discussion**

Inferences are that the valuing of models, patterns and case studies teachers used reflects that metaphorism epistemic style is an active variable in the epistemological function. However, the other variables in the epistemological function are dormant and when used might not bring about the epistemic therapeutic activity to ensure that science learners are at a good level of understanding science concepts taught in a Eurocentric technological infrastructure deprived school.
Conclusion

Epistemic therapeutic activities in science teaching can be achieved through understanding that epistemological function is made up of three variables; rationalism, empiricism and metaphorism. However, in Eurocentric technological infrastructure deprived schools, it is only the metaphorism epistemic style which is active as people construct knowledge socially and culturally.

References

Xu, X. (2013). What are the metaphors we live by? Theory and Practice in Language Studies, 3(8) 1467-1472.
Abstract

We compared the US and South African chemistry teaching assistants’ (TAs) TSPCK for chemical bonding. A sample comprised 67 chemistry TAs, 41 in the US and 26 in South Africa. A chemical bonding TSPCK instrument was administered to TAs. The instrument was designed to assess content knowledge and the five components of TSPCK namely Content representation, What is difficult to teach, Curricular saliency, Student prior knowledge, and Conceptual teaching strategies. TAs responses in the CK section were scored using a memorandum while responses in the TSPCK section were scored using a rubric on a scale of 1-4 corresponding to Limited, Basic, Developing and Exemplary PCK. Results show a significant difference between the US TAs and SA TAs TSPCK for chemical bonding. SA TAs demonstrated a developing level of TSPCK while the US TAs held basic TSPCK for chemical bonding. However, both groups demonstrated low chemical bonding content knowledge.

Introduction

Research has continued to show that students’ difficulties in understanding chemical bonding is due to its abstract nature, the way it is taught, and teachers’ low conceptual knowledge of the topic (Bergqvist, et al. 2015). This challenge calls for teachers’ sound content knowledge and pedagogical content knowledge (PCK) for chemical bonding to effectively teach it to their students. Shulman (1986) described PCK as interwoven pedagogy and subject matter knowledge necessary for good disciplinary teaching. Experts agree that PCK is topic specific, is more than subject matter knowledge alone, and develops over time as a result of teaching experience (Gess-Newsome, 2015). As such, Mavhunga and Rollnick (2013) developed a framework for measuring science teachers’ Topic Specific PCK (TSPCK) which has five components: Learner Prior Knowledge, Curricular Saliency, What is difficult to teach, Representations, and Conceptual teaching strategies. Teachers’ TSPCK plays a significant role in student learning (e.g. Mavhunga & Rollnick, 2013) in high school science classrooms. Equally, effective teaching of chemical bonding at university level requires college instructors to understand the content and how to teach it to students. Although studies have reported on teachers’ TSPCK for chemical bonding, little is known about the TAs TSPCK for chemical bonding. Additionally, there is a paucity of comparative studies on TAs’ TSPCK on chemical bonding. Thus, our collaborative research group is investigating TAs TSPCK for chemical bonding in the United States (US) and South Africa. At the institutions where this study was conducted, introductory chemistry courses and tutorial sessions are taught by TAs making them the primary source of basic
chemistry knowledge for undergraduate students. We assumed that: TAs were likely to find the TSPCK items on chemical bonding content knowledge, chemical bonding representations, and curriculum saliency easy to answer; TAs would struggle to answer the items on learner prior knowledge, what is difficult to teach, and conceptual teaching strategies; and as non-trained teachers, US and SA TAs have the same TSPCK levels for chemical bonding. We strongly believe that knowing TAs’ TSPCK for chemical bonding offers a significant potential for improving instruction on chemical bonding, and subsequently increase student learning. Thus, this study attempted to answer two research questions: What are the TAs’ CK and TSPCK levels for chemical bonding? Is there a difference between the US and SA TAs’ TSPCK for chemical bonding?

Methodology

A sample comprised 67 chemistry TAs, 41 at a US university, and 26 at South African university. All TAs were hired to teach general chemistry labs and tutorial sessions in their institutions. A valid instrument was used to test participants’ CK and TSPCK of chemical bonding. The TSPCK section was designed to assess five components of TSPCK (Mavhunga & Rollnick, 2013) namely, representations; what is difficult to teach; curricular saliency; student prior knowledge; and conceptual teaching strategies. In the CK section, participants were asked to explain the term chemical bond and describe the bonding in ammonia (polar bond), aluminium (metallic bonding) and magnesium bromide (ionic bonding). TAs responses in the CK section were assessed as a test against a memorandum while responses in the TSPCK section were scored and peer validated using a rubric with criteria on a scale of 1-4 corresponding to Limited, Basic, Developing and Exemplary PCK. Two chemical educators independently coded the participants' responses using the procedure described above. Mean scores were computed for each component. Then, independent t-tests were performed to find out if there were differences between the US and SA TAs’ CK and TSPCK for chemical bonding.

Results

Overall TAs’ TSPCK for Chemical Bonding: At-test revealed a significant difference (t (65) = -3.505, p =0.001) between the US and SA TAs’ TSPCK levels for chemical bonding. The TSPCK mean score for SA TAs (m=62.83, sd= 10.74) was significantly higher than the mean for US TAs (m=53,sd=9.84). This result suggests that SA TAs had more sophisticated TSPCK than the US TAs.

TAs’ performance on TSPCK components: Data was analyzed to establish the performance of TAs on five components of TSPCK. There was a significant difference between the US and SATAs’ performance on Bonding representations (REP) (t (65) = -2.81, p=0.007). The mean score for SA TAs (m=2.82, sd=0.56) was significantly higher than the mean score for the US TAs (m=2.33, sd=0.76). These results suggest that SA TAs showed they were at the Developing knowledge level while the US TAs demonstrated the Basic knowledge level of chemical bonding representations.
Similarly, SA TAs out-performed US TAs on the What is difficult to teach (WDT) component (t (65)= -5.774, p=0.000). SA TAs demonstrated Developing knowledge level (m=2.88, sd = 0.59) while the US TAs performed at the Basic knowledge level (m=1.98, sd=0.65) of WDT.

On the Learner Prior Knowledge (LPK) TSPCK component, SA TAs had a higher mean score (m = 2.56, sd, 0.66) than the US TAs (m=2.12, sd=0.38). The difference in the mean scores was significant (t (65) = -3.55, p= 0.001). SA TAs showed Developing knowledge level on LPK while the US TAs demonstrated Basic knowledge level of LPK.

We also found a statistical significant difference between the US and SA TAs on Conceptual teaching strategies (CTS) (t (65)= -2.46, p= 0.017). SA TAs demonstrated Developing knowledge level of teaching strategies for chemical bonding (m=2.4, sd= 0.91) while the US TAs (m=1.88, sd= 0.82) showed Basic knowledge level of how to teach chemical bonding.

On the other hand, there was no significant difference (t (65) = -1.85,p= 0.069) between the US TAs (m= 1.44, sd= 0.53) and SA TAs (m= 1.66, sd=0.35) on chemical bonding content knowledge (CK). Both groups demonstrated Basic knowledge level of chemical bonding. Similarly, the mean for the US TAs (m=2.49, sd=0.50) was not significantly different (t (65) = -0.829, p=0.410) from the mean score of SA TAs (m=2.59, sd=0.48) on Curriculum saliency (CS). Both groups demonstrated Developing knowledge level on curriculum saliency.

Conclusions

In general, SA TAs demonstrated more sophisticated TSPCK for chemical bonding than their US counterparts. Although SA TAs performed better than US TAs on three components of TSPCK - REP, WDT, and LPK both groups demonstrated limited level knowledge of CK and CS. These findings have implications for chemistry teaching and learning at university level. For example, the results suggest the need to address chemical bonding content knowledge and curriculum saliency among TAs in both institutions.

References


USING COGNITIVE LOAD THEORY TO INFORM THE DESIGN OF AN INCLUSIVE MINI SPEC

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Abstract
An understanding of cognitive load theory was used to re-design an existing low-cost spectroscopy experiment. Minimizing the extraneous load in the design of the Mini Spec was paramount for two reasons. Firstly, the subject matter is intrinsically challenging. Secondly, the processing capacity of the working memory is reduced in a South African context as the majority of students are English second language speakers. Extraneous cognitive load was minimised by simplifying the design of the Mini Spec template, and by radically changing the format of the construction instructions. The original written instructions were used by a control group for the construction of the Mini Spec. In the experimental group, tangible templates (in various stages of construction) supplemented the original instructions. Construction time was the assumed proxy for the cognitive load of the task and was measured in both groups. The findings showed the experimental group required less time on construction and out-performed the control group in the marks achieved in the report sheet write up. Informally, the portable nature of the Mini Spec enabled its dissemination outside of the academic laboratory setting into the home lives of the student where it was met with positive reactions.

Introduction
Spectroscopy and emission lines are areas where novice students struggle due to the abstract nature of the content and the ease with which misconceptions arise or persist (Burman, 1991; Jones, 1991; Sadler, 1991). This problem has been addressed since the 1990’s by adding demonstrations and experiments with individual spectral tools (Forbes & Nothling, 2014; Vanderveen et al., 2013; Wakabayashi, 2008; Schwabacher, 1999; Jacobs, 1997; Finkenthal et al., 1996; Brouwer, 1992). However, when dealing with academically underprepared, English second language (ESL) students with limited laboratory experience on an under-resourced extended degree programme; available spectral tools and methodologies do not suffice. In this paper, Cognitive Load Theory (CLT) was the theoretical framework used to re-design an inclusive spectroscopy experiment.

CLT is a theory on how learning works, it seeks to understand the factors which influence the availability of working memory in the mind of the individual. According to Paas et al. (2003), total cognitive load is the sum of intrinsic, germane and extrinsic load (see Figure 1). Intrinsic load is specific to the topic at hand and cannot be altered: for example, the unfamiliarity, inherent complexity and difficulty of spectroscopy and emission spectra. Germane load represents the
purposefully embedded schema or cognitive structures in the learning materials which allows for better functioning of the individual’s working memory. Pivotal in this study was extraneous cognitive load, which is imposed by the format of the learning materials, as it has an adverse influence on the available working memory. Fortunately, extraneous cognitive load can be manipulated, for example by altering the layout of the learning material.

Figure 1. A representation of Cognitive Load, adapted from Seery (2012) and annotated by referring to Pass et al. (2003).

CLT was used to inform the understanding of learning used in this study, inclusive South African education was the application thereof. Inclusive education encompasses a wide spectrum and has fluid meaning dependant on its use internationally, at a country specific level or even within an institution; the broad definition of inclusive education practices being the removal of barriers to student participation and learning (Ainscow, 2005; Department of Education, 2001). This study focuses on two particular facets from the definition in White Paper 6 (Department of Education, 2001, 6):

- Acknowledging and respecting differences in learners, whether due to age, gender, ethnicity, language, class, disability, HIV or other infectious diseases.
- Broader than formal schooling and acknowledging that learning also occurs in the home and community, and within formal and informal settings and structures.

The main thrust of this study was to remove language as a barrier, as in the first bullet, in the spectroscopy laboratory, as the majority (≥80%) of the 500 students enrolled in the general chemistry course were ESL. This is of great importance as it has been found that ESL speakers use up to 20% of their available working memory’s processing power in language related tasks instead of learning or problem solving (Johnstone & Selepeng, 2001).

Secondly, international concerns have been raised as to the authenticity, quality and aims of informal scientific learning (Pratt & Yezierski, 2017; Braund & Reiss, 2006). The aim of this study was not formal outreach but rather informal learning in the home and community via informal outreach. This study sought to be in line with the majority of the “Purposes for Outreach” isolated by Pratt and Yezierski (2017) which include curiosity, interest, accessibility, supplemental education and motivation towards future study.
**Mini Spec**

As mentioned, there are varieties of educational spectroscopic tools available in literature. In deciding on a tool for this study, the following considerations were of importance:

1. Cost was of the highest priority, as no additional resources were available.
2. The level of skill and understanding required of the student needed to be minimal as the study was set in an extended programme chemistry course.
3. The benefits of the spectroscopic tool should be transferrable to informal learning, as tertiary institutions are focusing on surrounding community upliftment and integration.

The mini spectroscope (Schwabacher, 1999) met these considerations and was re-designed, with permission, as the Mini Spec (see Figure 2).

![Figure 2: Left, original design Schwabacher (1999). Right, modified Mini Spec design.](image)

**Methodology**

Quantitative data is presented in this paper. The analysis of external observations, Think Aloud Livescribe discussions and surveys on learning gains is on-going. In this study large student numbers (535) were involved. Approximately 100 students were divided between two laboratories during an experiment. This provided the opportunity to provide supplemental templates in various stages of construction throughout the experimental laboratory, whereas only written instructions were provided in the control laboratory.

**Research Questions**
1. What were the benefits of supporting extraneous load for ESL students in the laboratory?
2. What was the extent of dissemination of the Mini Spec outside of the academic environment?
3. What were the reactions of the public to the students’ Mini Spec tools?

**Data Collection Methods and Limitations**

1. Time recorded by each student, in minutes, for the completion of the construction of the Mini Spec
2. Qualtrix survey at the end of the semester, probing the Mini Spec dissemination in non-academic environments

Time was taken as a proxy for the extraneous cognitive load of the construction of the Mini Spec. However, the pace at which students work is known to be variable, for example, some students work naturally faster than their peers. The large numbers in each group should mitigate individual speed variations. The Qualtrix survey was voluntary and required participants to have internet connectivity.

**Findings**

Upon consideration of the descriptive statistics (see Figure 3), construction time for the control (M = 23.2 min, SD = 7.7 min, n = 214) was hypothesised to be greater than the construction time for the experimental group (M = 21.2 min, SD = 6.9 min, n = 194). Before running a one-tailed t-test, the F-test was used to establish that the variance was equal between the two groups. The findings of the t-test showed that the difference in the construction time taken between the control and experimental group was in fact significant, t (406) = 2.76, p = 0.003, Cohen d = 0.4.

![Figure 3: Box and whisker plot of construction time per group](image)
According to external observations, the reduction in time on building did not translate into less time spent in the laboratory, in fact it allowed for slightly more time working with the Mini Spec and discussion thereof with peers, lab demonstrators and lecturers.

At the onset of the study, it was not expected that a perceptible difference would be seen in the students’ performance in the report sheet that they submit at the end of the laboratory session. The performance for the control (M = 68.9%, SD = 12.2%, n = 214) was not expected to be statistically different from the performance of the experimental group (M = 73.2 %, SD = 10.1 %, n = 198), see Figure 4. However, the difference was in fact significant, t (405) = 3.98, p = 0.00005, Cohen d = 0.4 (one tail t-test, unequal variances).

The voluntary Qualtrix survey had a response rate of 38.4% at the end of the semester. Of the survey participants, two thirds said that they returned home with their self-constructed Mini Specs (see Figure 5). Furthermore, 60% of those who took the Mini Spec home shared it informally with the people around them. This informal sharing was done with a wide variety of members from the students’ homes and communities (see Figure 6).
The final item in the survey asked students to reflect on the reactions from the people with whom they shared and explained the Mini Spec. The results were overwhelmingly positive, with more than 97% of those exposed informally reacting with interest (see Figure 7).

What was their reaction to the Mini-Spec?

Conclusions

The reduction of cognitive load in the minds of the student in the laboratory had several benefits: the construction time was lessened and in turn enabled more time for cognitive processing which correlated with stronger performance in the student’s report sheet write up.

The findings of the Qualtrix survey were broad, yet positive in terms of high rates of dissemination and public interest. This shows that the nature of the Mini-Spec, and the self-efficacy students felt upon completion, were sufficient to initiate unsolicited informal inclusive learning in their homes and communities. To gain further insights of the informal learning which took place, interviews or focus groups would need to be conducted: student participants would need to be probed as to their roles in the interactions and the reactions which they encountered. As such there was not sufficient data to explicitly determine which of the “Purposes for Outreach” (Pratt & Yezierski, 2017) have been met.
in the study. Of particular future interest may be the impact that initiating informal learning has on the individual learning of the student.

References


EXPLORING KNOWLEDGE PROGRESSION AROUND THE EARTHS’ MOVEMENT IN SPACE IN CAPS, PRIMARY SCIENCES

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What separates informal and formal learning is that the latter uses a curriculum. A curriculum can be defined as a school or college programme of teaching and learning. It contains prescriptions of suggestions of what and how content is taught, attitudes and skills to be developed in learners and guidelines for assessments for each topic and at each level of learning (Nelson, Jacobs, & Cuban, 2009). In addition, there is no perfect curriculum. Hence, Luckett (2009) views curriculum as either objective or subjective in nature.

Current arguments in school science focus on achieving scientific literacy for all (NRC, 2007) to prepare children for continuous advancement of technological developments (Wheelahan, 2012). Thus, the beginning of each year in South Africa, when matric [school leaving exam] results are released, the main focus is on the sciences.

Research focusing on how to improve and attract learners to the sciences, especially in physics has seen other scholars focusing on knowledge progression across different science topics from primary level to tertiary level of learning. Willard and Roseman (2007) argue about the need to teaching learners powerful knowledge which is interconnected through developing knowledge progression. On the other hand, Plummer, Palma, Flareda, et al. (2015) acknowledge the challenges ahead in trying to validate learning progressions. Alonzo (2018) views knowledge progressions as powerful tools which can be effectively used by teachers for formative assessments.

This study thus explores knowledge progression around the Earth’s movement in space [EMIS] theme in the South African natural sciences curriculum (DBE, 2011a). Arguments around whether a curriculum is a kilometre wide and thirty centimetres deep or vice versa are quite common.

We admit that the concepts around the EMIS are abstract and complex. They are so abstract that, even the use of models may not adequately represent exactly what happens in space which learners need to conceptualise. The reason being that, the sizes of the Earth and Sun are gigantic and incomparable to anything that children have seen. Secondly, the movements of the Earth in space are so sophisticated that they oppose experiences of the Sun and the Earth that we inhabit. Thirdly, dealing with abstract and complex concepts also require teachers who understand the levels of understanding of most learners to find powerful strategies for teaching (Shulman, 1987).
In view of the challenges cited above, having topics with concepts that are connected may be an advantage. This will allow for more teaching and learning time on a topic. The aim being to empower learners with powerful knowledge. Powerful knowledge in the school science curriculum that develops from being context bound and horizontal, developing to becoming abstract, complex and vertically specialised types of knowledge (Hugo, 2012). Thus, schools are expected to develop learners’ cognitive reasoning from concrete contextualized to abstract, complex and specialised forms of knowledge as they advance in grades (Shay & Steyn, 2016). Powerful knowledge enables a participant to navigate between context and generalisations without losing meaning, [we will define powerful knowledge later]. This enables a learner to move between contexts and apply knowledge in meaningful and relevant situations (Scott, Mortimer, & Ametller, 2011). Thus, construction of new and sophisticated knowledge does not happen in a vacuum, but through negotiation and realignment within learners’ minds.

Although, there seem to be an interest in ‘knowledge progression’ research, literature around knowledge progressions in primary astronomy is limited. In this discussion, by knowledge progression refers to the thinking behind the presentation and progression of conceptual knowledge in the curriculum within a grade and across grades (Alonzo & Gotwals, 2012). Thus, we are exploring the linking threads within the EMIS theme.

It is important to have an understanding about how concepts are developed because, extant literature around the teaching and learning of EMIS concepts in primary school science confirm that some teachers face challenges similar to those faced by most learners (Govender, 2011; Kikas, 2004).

In this discussion, we explore knowledge progression in the EMIS theme across the South African primary sciences, from Grades R to 7. There are four phases within the South African Education system from Grade R to 12. Grades R to 3 are in the Foundation Phase, 4 to 6 are in the Intermediate Phase, [these constitute primary schooling]. Grade 7 to 9 are in the Senior Phase and lastly, grades 10 to 12 are in the FET phase (DBE, 2011). Grade 7 is included because most primary schools have up to grade 7 and learners only leave when going to grade 8.

In Grade R, science is under (beginning knowledge) in life skills in South Africa. From grade 4, which marks the beginning of Intermediate Phase [IP] natural sciences and Technology [NS & T] becomes a subject. Astronomy is also introduced from grade 3 (DBE, 2011). In fact, the Department of science and Technology regard astronomy as a ‘shop window’ into the sciences (DST, 2002). Thus, the need to teach and learn astronomy meaningfully will increase, especially with the developments in the Square Kilometer Array [SKA] in the Karoo.

In order to understand the progression of knowledge around the EMIS concepts, the researchers develop translation devices which are a form of an external language used to analyse any discourse in research. The idea of external languages as translation devices is a development of Bernstein’s (1971) concept of classification and framing by Karl Maton (Maton & Doran, 2017). Maton provides
a multi-purpose tool box and from it, we chose the semantic gravity [SG] and semantic density [SD] for our discussion.

**Theoretical Framework**

Both SG and SD have code qualities (Maton & Doran, 2017). Semantic gravity will be discussed first, in terms of its use as an analytical tool. Secondly, semantic gravity translation device [SGTD] will be developed. Following the same format, the SD, will be discussed followed by the development of a semantic density translation device [SDTD] in the same way as for semantic gravity. This means that two translation devices will be drawn.

**Semantic gravity [SG]**

Maton (2014) defines semantic gravity as follows:

Semantic gravity (SG) refers to the degree to which meaning relates to its context. Semantic gravity may be relatively stronger (+) or weaker (−) along a continuum of strengths. The stronger the semantic gravity (SG+), the more meaning is dependent on its context; the weaker the semantic gravity (SG−), the less dependent meaning is on its context, (p. 36).

In using SG+ and SG− as an analytical tool, the researchers interpret meaning in terms of dependence of meanings to the context presented in the curriculum. In the SGTD, SG+ means very strong semantic gravity. Meaning is embedded in context, is experienced and or observed. SG+ is less embedded in context but demands the application of prior knowledge or perception to understand.

For weaker semantic gravity [SG−] in the translation device, there is a shift towards abstraction or highly abstract [SG− −]. Thus, weak SG−, sentences describe phenomena which cannot be directly experienced from the Earth. An example of such sentences from the curriculum is from a Grade 4 excerpt; “the Sun is very big (much bigger than the Earth),” (DBE, 2011, p. 27). In order for learners to understand the abstract concept, models are used to foster correct mental model development. Below is a SGTD with excerpts from the curriculum starting with SG− −.

<table>
<thead>
<tr>
<th>Code</th>
<th>Indicator</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very weak</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SG  − −</td>
<td>Most abstract. The descriptions about the Earth that cannot be directly</td>
<td>Grade 3 Stars and planets - what they are</td>
</tr>
<tr>
<td>SG↑</td>
<td>observed or experienced from a single location on the Earth. Uses the SFR.</td>
<td>Grade 4: the Sun is very far away, but is the closest star to the Earth.</td>
</tr>
<tr>
<td>Weaker SG−</td>
<td>Concepts are described using everyday terms The knowledge can only be</td>
<td>Grade 4 the Earth is round like a ball (sphere) and is made of rock</td>
</tr>
<tr>
<td>−</td>
<td>imagined through mental visualizion.</td>
<td>the Sun is very big (much bigger than the Earth)</td>
</tr>
<tr>
<td>More</td>
<td></td>
<td></td>
</tr>
<tr>
<td>abstract</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SG↑</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The concepts which are classified under SG - - and SG - are under big idea 1. The concepts require an understanding based on the SFR. Big idea 1 consists of conceptual knowledge of properties of the Earth as one of the celestial objects. This knowledge is in Grades 3 and 4 in the CAPS (DBE, 2011a).

<table>
<thead>
<tr>
<th>Strong SG⁺ Concrete SG↓</th>
<th>Describes child’s perceptions as a result of observable interaction with the world [EFR]</th>
<th>Foundation Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Grade R:</strong> The weather in summer, autumn, winter, &amp; spring</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• How nature is affected</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• How animals are affected</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What the sky looks like - include colour and clouds</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Grade 1:</strong> Regular observation of weather conditions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Hot, cold, windy, cloudy, sunny, misty, rainy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What the night sky looks like</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Grade 2:</strong> The four seasons</td>
</tr>
<tr>
<td></td>
<td></td>
<td>How seasons affect growing things - sowing, growing and harvesting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>How seasons affect animals - include farming e.g. sheep shearing, animal dipping; birds e.g. migration and nesting (CAPS, p. 43).</td>
</tr>
<tr>
<td>Very strong SG ++ Concrete and most bound SG↓</td>
<td>Knowledge is from child’s everyday experience. EFR</td>
<td><strong>Grade R:</strong> Weather</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hot days, cold days, sunny days, rainy days, windy days</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- include what we wear on these days and games we play</td>
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<td></td>
<td></td>
<td><strong>Grade 1:</strong> The weather and us - include clothes, food, activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>When we can see the moon</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Grade 2:</strong> How seasons affect us - clothes, food, activities Things I do at night - get ready for bed, read and tell stories,</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Grade 4:</strong> from the Earth, we can see the Sun, Moon and stars</td>
</tr>
</tbody>
</table>

The concepts cited above under SG⁺ and SG ++ are under Big idea 4: Big idea 4 consist of concepts that are context bound and observable from the child’s environment. The observer uses the EFR, meaning that knowledge is concrete. In the CAPS this knowledge is generally in the Foundation Phase, specifically Grades R, 1 and 2 (DBE, 2011b).

Table 1: The Semantic gravity translation device [SGTD]

**Semantic density [SD]**

Maton (2014) defines semantic density as:

Semantic density (SD) refers to the degree of condensation of meaning within socio-cultural practices, ... Semantic density may be relatively stronger (+) or weaker (−) along a continuum of strengths. The stronger the semantic density (SD+), the more meanings are condensed within practices; the weaker the semantic density (SD–), the less meanings are condensed. The degree of condensation within a practice relates to the semantic structure in which it is located, (p. 37).
By using SD, we describe the shifts in degrees of complexity of knowledge as portrayed in the meaning. Semantic density may be stronger [SD+] or weaker [SD-] in a concept. The stronger the semantic density, SD+, the more the meanings are condensed within a concept or a sentence/phrase.

The weaker semantic density, [SD-] relates to a static state. The attributes of Earth as viewed from space. Here, the concept calls for factual descriptions of the Earth as a system being viewed from space, the astronomical knowledge. SD-- is a dimension of weakness and it relates to the characteristics of the Earth that are unrelated to its movement in space, but static. Here the descriptions entail knowledge about the Earth’s physical structure, soils, and calls for the geological knowledge.

<table>
<thead>
<tr>
<th>Code</th>
<th>Indicator</th>
<th>Example</th>
</tr>
</thead>
</table>
| SD+    | The detailed characteristics of an object in a system | **Grade 4** --the Earth gets the right amount of light and heat from the Sun for supporting life.  
- the Sun provides heat and light to the Earth for living things  
**Grade 5**: The sun, planets and asteroids  
there are eight planets and the asteroid belt (Mercury, Venus, Earth, Mars, Asteroid Belt, Jupiter, Saturn, Uranus, and Neptune) in orbit around the Sun Names of the planets (p. 56). *Repeated in grade 6*  
-the planets and asteroids take different amounts of time to revolve around the Sun* Names of the planets (p. 56).  
**Grade 6**  
each planet has its own -- features, size, orbit and position in relation to the Sun, composition (rocky and gas planets) and number of moons (some have no moons) Repeated from grade 5  
**Grade 7**  
- the Earth receives energy from the Sun in the form of heat and light (solar energy)                                                                 |
| SD+    | Dynamic                                        | *Repeated in grade 6*                                                                                                                                                                                  |
| SD+    | Most complex. The ideas are brought together   | **Grade 6**  
-in our Solar System, each planet rotates (spins) on its own axis - the planet Earth is spinning, and one complete rotation takes about 24 hours. We experience this as a day and a night (p. 62).  
- planet Earth revolves around the Sun in its own orbit (pathway), and one complete revolution takes 365 ¼ days. We experience this as a year  
**Grade 7**  
due to the tilt of the Earth, the intensity of the solar energy (amount per unit area) that reaches different parts of the Earth changes through the year.  
- differing intensities of solar energy reaching the southern and northern hemispheres through the year lead to the four seasons  
- when the solar energy falls more directly on the southern hemisphere, the solar energy is spread over a smaller area and it is summer in the southern hemisphere  
- when the solar energy falls obliquely (at an extreme angle) on the southern hemisphere, the solar energy is spread over a wider area and it is winter in the southern hemisphere                                                                 |

597
Attributes an object on its own

Grade 5 - the Earth moves
-- the Earth takes about 365 days to travel once around the Sun, this is called a year

Grade 6 -- during rotation, the side of the Earth facing the Sun experiences daytime, and the opposite side of the Earth experiences night-time

Attributes of the Earth that are unrelated to its movement in space but the physical attributes

Grade 3 - Earth from space - what it looks like (land, sea, clouds)

Grade 4 - the Earth has many different habitats for living things
- the main surface features of the Earth are land (rocks and soil), water and air
- most of the surface of the Earth is covered with water (oceans and seas)
- the land we can see is made up of continents* and islands
- there is a thin layer of air surrounding the Earth

Grade 5 - soil, air, water and sunlight support life on Earth
- soil supports life on Earth
- the Earth spins on its own axis
- the Earth takes about 24 hours to spin once; this is called a day
- the surface of the Earth is called the crust, and consists of rocks (even under the oceans), and soil

Grade 7 - dead plants and animals can eventually form coal, oil or gas (fossil fuels) after millions of years; this happens when:
-- the remains of dead plants and animals are covered by layers of mud and soil
- the layers press down on these remains
-- more layers lead to increased pressure
-- increased pressure, over long periods of time, changes these remains into coal, oil or gas

Table 2: The Semantic density translation device [SDTD]

Discussion

Using information from tables 1 and 2 above, how does the conceptual knowledge relating to the Earth’s movement in space in the Primary Natural Sciences curriculum progress?

<table>
<thead>
<tr>
<th>Big idea 1</th>
<th>Big idea 2</th>
<th>Big idea 3</th>
<th>Big idea 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Earth’s movement in space causes variation observable on Earth SG++/+ Description is experienced and based on a child’s perception about the world from the Earth’s view point</td>
<td>The Earth is a planet in the solar system SG --/- Descriptor is most abstract and abstract, using the space view</td>
<td>Earth’s rotation/spin on its axis-causes cycles such as day &amp; night. SD -- and SD- An idea around the object’s behaviour</td>
<td>Earth’s orbit/revolution around the Sun. It causes seasonal cycles SD ++ and SD + Most complex ideas and interactions are introduced</td>
</tr>
</tbody>
</table>

Table 3: Big ideas and the translation device
Table 1 above, in the descriptor and given example, for SG--/- deals with ideas of characteristics objects that are in space. The most abstract concepts start in grade 5, where learners are introduced to the Earth moves concept. The Earth moves (revolves) concept is categorised as big idea 4.

For SG ++ /+, the ideas are bound in context and influenced by a child’s views about his/her environment and views about the world from the child’s perspective. These ideas are in grades R to 2 in the Foundation Phase. The SD - - and SD – are concepts about an object’s behavior which as an astronomical object. These concepts start from grade 4 up to 7. The SD ++ and + represents concepts that are very complex to very complex and dynamic relationships. For example, the reasons for seasons in Grades 6 and 7 requires application of the impact of direct light energy on an object versus oblique light on an object. Understanding the angle of tilt of the Earth, and others.

**Conclusion**

We argue that powerful knowledge should not be based around the quantity of content learnt which is in isolation to the whole (Scott et al., 2011). Based on the findings around how children learn, Vosniadou (2001) and Scott et al., argue that children in primary school especially need to engage with an idea in order to understand. What this means is that, just exploring how conceptual knowledge around the EMIS develops may not inform us about knowledge developing as segments or as cumulatively developed (Maton, 2009). In order to answer this question fully, focus group interviews will be done. We conclude that there seems to be progression of ideas, from being context bound, to abstract to complex, then very complex and dynamic ideas of the object in space in its interactions with other objects in space and the result.

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DBE. (2011b). Curriculum and Assessment Policy Statement Grade R-3 Life Skills. Pretoria: Department of Basic Education Government of South Africa


AN EXPLORATION OF THE USE OF AN INQUIRY BASED APPROACH IN TEACHING SCIENCE USING EASILY ACCESSIBLE RESOURCES
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Abstract
The use of hands-on practical activities in science education is highly recommended in many curricula across the globe. In this study, we explored the benefits of using easily accessible resources in mediating learning of inquiry-based practical science lessons. Essentially, the inquiry-based practical activity was based on designing mini-ecosystems. Data were generated through observations, small group and whole class discussions, mind maps and concept maps. A thematic approach to data analysis was adopted and Vygotsky’s social constructivism was used as a theoretical lens. The findings of the study revealed that the inquiry-based approach created an enabling environment for student engagement, arguments and meaning making of scientific concepts. However, since this study is work in progress, more data will be collected in the form of teachers’ reflections on their own experiences of doing mini-ecosystems with their own learners.

Keywords: Natural Sciences, inquiry based practical activity, easily accessible resources, social constructivism

Introduction
Teachers and educational researchers agree that the value of practical activities in science education should not be overemphasised (Abrahams & Millar, 2008; Millar, 2010). Many science teachers readily agree that students enjoy science lessons involving ‘hands-on, minds-on and words-on’ practical activities (Maselwa & Ngcoza; 2003; Mavhunga & Kibirige, 2018). However, research shows that in many cases students’ interest is not a true measure of the amount of learning that takes place in those practical lessons. For instance, Hodson (1990) and Abrahams and Millar (2008) critique the way teachers conduct practical lessons, which they feel are in most cases unproductive and ill-conceived. These scholars often blame the traditional recipe approach used by teachers in practical science lessons, whereby students are given a set of prescribed procedures to follow.

In South Africa, finding new ways of teaching science is of paramount importance as a turn-around strategy to improve the poor performance in Science. Such poor performance could be exacerbated in part by the lack of resources or inadequate practical activities conducted in schools. Regarding lack
of resources, in her study Asheela(2017) revealed that the use of easily accessible resources when doing inquiry practical activities can enhance learning of science concepts in under-resourced schools in particular. To Schwartz, Lederman and Crawford (2009), scientific inquiry refers to the methods and activities that lead to the development of scientific knowledge. As an attempt to promote scientific inquiry in science classrooms, Maselwa and Ngcoza (2003) introduced the Predict-Explain-Explore-Observe-Explain (PEEOE) approach, which entails learners making predictions and providing explanations thereof before they do and observe the activities. This study was triggered by these innovations and it sought to address the following research question:

What are the benefits of using easily accessible resources in mediating learning of inquiry based practical science lessons?

Theoretical Framework

This study is informed by Vygotsky’s (1978) social constructivist theory. This theory recognizes the importance of social and personal aspects of learning (McRobie & Tobin, 1997). It further asserts that social interactions and participation result in meaningful learning (Sedlacek & Sedova, 2017). Additionally, students are central in the learning process. From this theory, key concepts were considered, namely, mediation of learning, zone of proximal development (ZPD) and self-regulation. The study also recognizes that language is central to all these concepts.

Research Design and Methodology

This study is underpinned by an interpretive paradigm. Within the interpretive paradigm, it took the form of a qualitative case study (Bertram & Christiansen, 2015; Cohen, Manion & Morrison, 2011). Bertram and Christiansen (2015) contend that a case study enables the researcher to collect rich qualitative data that will give him/her an in-depth understanding of phenomena. The phenomenon and the unit of analysis in this study was to understand the benefits of inquiry based practical science lessons.

Sample and Data Collection

A class of 28 second year BEd Science in-service teachers were involved in this study. To collect data, they were divided into four groups of seven. Each group was required to design a mini-ecosystem using a glass bottle, soil, water and plants from the local environment. Firstly, however, they were asked to predict and explain what would happen if the plants were planted in glass bottles containing moist soil, sealed and placed on the window seal where they would be exposed to sunlight. They were given some newsprints to write down their predictions and explanations thereof. During the discussions, we observed that the students discussed in isiXhosa, their mother tongue. However, during their presentations they used English. This underscores Vygotsky’s (1978) assertion that language is a powerful psychological tool that mediates thought processes as one engages in
interpersonal social interactions. From the students’ explanations of their predictions, emerging key concepts were used to introduce them on how to make mind-maps and concept-maps. Thereafter, they went to the garden to do the experiments (out-of-classroom context) and the glass bottles were placed on the window seal for observations over time. Furthermore, they were tasked to do the same inquiry based practical activity with their own learners at their schools.

**Data analysis, Validity and Trustworthiness**

For data to make sense, Bertram and Christiansen (2015) suggest that it should be systematically organised into categories and themes. Qualitative data were thus analysed inductively and deductively using the Vygotsky’s (1978) social constructivist theory as a lens. Essentially, we were interested in the social interactions and self-regulation during the inquiry based practical activity. Additionally, we were interested in how the in-service science teachers made sense of the scientific concepts that emerged from the activity. As proposed by Merriam (2009) and Creswell (2012), validation in qualitative research is critical. To validate and enhance trustworthiness of data in this study, brainstorming, discussions, documentary evidence in the form of newsprints and journal reflections were used.

**Findings and discussions**

It emerged from this study that inquiry practical activity promoted students’ active engagement and participation (Sedlacek & Sedova, 2017; Vygotsky, 1978). Furthermore, the use of isiXhosa enhanced arguments amongst the groups and the predictions enabled the students to value each other’s ideas. In their predictions and explanations thereof, all the four groups predicted that the plants in the sealed glass bottles would die after some time because there would be no air getting in the sealed glass bottle. They elaborated that oxygen in the air was essential for cellular respiration. Similarly, carbon dioxide was essential for the photosynthesis process. In their reflections, the in-service teachers indicated that they found the activity very exciting and they would like to try it with their learners.

**Concluding Remarks and Recommendation**

It emerged from this study that the social interactions stimulated by the mini-ecosystem inquiry practical activity enhanced student engagement, arguments as well as meaning making of scientific concepts. The use of isiXhosa during the discussions proved to be a useful catalyst in promoting active participation amongst the students. Similarly, the out-of-classroom context and use of easily accessible resources made the students to realise the importance of improvisation. The study thus recommends there is a need for continuing professional development programmes that support science teachers on how to enact inquiry-based approaches using easily accessible resources in their classrooms.
References


FRAMING DEVELOPMENT OF KNOWLEDGE BASE FOR PROMOTING SOCIO-SCIENTIFIC LITERACY: Science Teachers’ Case Studies

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Abstract
Climate change has come to be recognised as a self-inflicted humanitarian crisis promising to devastate every community across the globe. Solutions to mitigate its impact lies in disrupting the mind set and values which forms the modern lifestyles on which the current civilisation is founded. No doubt that education as a means for social engineering is key and for defensible reasons, many studies argue that quality science education is paramount in mitigating the impacts of this socio-scientific phenomena. In South Africa, several studies reported a retreat in the physical sciences schooling curriculum in addressing scientific literacy as well as on topics dealing with climate change. This paper presents a theoretical framework on PCK for scientific literacy drawn from literature as well as the work I am doing with my postgraduate students who in their roles as practicing classroom science teachers undertook self-studies using action learning methodologies. The overall project was aimed at interrogating and refining the aspects of Learning for Teaching through Participation (LTtP) model which are related to open inquiry and scientific investigation as well as issues of relevance and social scientific literacy. Data from the various case studies was used to synthesise and refine what is referred to a Beliefs–Practice cross-case analysis matrix, which is used to depict each teacher’s changing profile towards curriculum reform-aligned approaches by subjecting and interrogating the relevant three of the six aspects of PCK. This paper presents the two tools as well a brief outline of the literature and empirical studies on which the work was founded.

Introduction
Climate change is a complex cross cutting interdisciplinary phenomenon which was carefully selected as a focal theme in this project because of its worldwide significance and the humbling impact it holds on our lives. Causes of climate change are embedded in our values and lifestyles as communities and therefore scientific literacy carries a lot hope as an engine for driving massive change in mitigating these unfolding catastrophic effects of climate change. Education remains a powerful vehicle for imparting new ideas and transforming societies and therefore, there is no doubt that the best place to start is with learners in the classrooms. In South Africa, several studies reported a retreat of the national science schooling curriculum on issues of scientific literacy and societal relevance. There is indeed a need for a careful and urgent relook at the foundations, structure and nature of the science education we offer in schools as it pertains to societal relevance because
prospects in mitigation of climate change are locked in levels of literacy of the masses and in the possibilities of engaging in critical lifestyle changing reflections. This study is aimed at contributing to developing capacity for integration of education for sustainability and climate change literacy in science classrooms. The study engages and supports science teachers in their efforts of using their own teaching, to raise communities of learners who can become agents of change in their own schools and larger community. In this paper, I share one of the outcomes of this research which serves as a framework for framing teacher learning environment in developing PCK for scientific literacy.

The Theoretical and Empirical foundations of the Framework

Several studies allude to the fact that teachers not only have limited knowledge of climate change concepts but that they do not appreciate its contested nature nor are they aware of the currently prevailing disputation with regards to the nature and causes of this global crisis. Some studies on issues of PCK for socio-scientific literacy argue for teachers’ adequate knowledge of climate science coupled with knowledge of nature of science and scientific inquiry (Anyanwu et al., 2015) while others insist on transformative teaching methodologies (Veron et al., 2016) as critical for dealing with this complex socio-scientific issue in teaching. On issues of teacher change, many studies have revealed the critical role played by teachers’ beliefs in the process of reform because of their resistance to change. The study employed an eclectic theoretical approach with multidimensional analytic framework guided by the four models as follows:

- **The Interconnected Model of Professional growth** (Clarke & Hollingsworth, 2002)
- **School Curriculum Implementation model** (Rogan & Aldous, 2005)
- **Teacher Belief Interviews and Maps** (Luft & Roehrig’s (2007); Luft, 2009)
- **The model for socio-scientific reasoning** (Sadler et al., 2007)

In this project, I worked with my post graduate students to explore and identify salient elements of practical work as an effective pedagogical resource (Sithole, 2014; Nzimande 2015; Kufa, 2015; Sithole, 2016) and on issues of relevance focus on climate change as a powerful compelling socio-scientific theme (Nakedi, 2014; Mlangeni, 2008; Newell, 2008; Nkosi, 2010; Simango, 2017) as well as Chipato and Chigura (pending MSc studies) in the learning and teaching of science. The LTtP was used iteratively with literature and emerging data further modified while serving as a tool to map, categorise and analyse teacher change data. Change in one domain is translated into change in another through mediating processes of reflection and enactment. The teachers’ reflective journals, progressive concept maps and CoRes, as well as planning and teaching artefacts generated during the process, were the main sources of data.

**The Learning for Teaching through Participation (LTtP) model**

The LTtP is premised on the need for a shift of perception from seeing professional development programs as changing teachers to seeing teachers as active learners, shaping their professional growth through reflective participation in professional development and in practice. Following a
situated perspective to learning this model (figure 1) expounds that any process involving teacher professional growth will naturally be subjected to the constraints and affordances of the enveloping change environment derived from 6 factors such as teacher & school collegiality, school management and ecology, resources and time constraints, external factors, learners and teacher factors.

This framework identifies three interrelated domains which encompass the teachers’ professional world and presents multiple professional growth pathways. Change, from one domain to the next happens through the mediating processes of enactment and reflection which are indicated through arrows. The domain of knowledge and views pertains to all the capacities, thought processes and dispositions inherent in each teacher which prompts certain professional actions and responses to different situations in their work and thereby gaining expression within the domain of action and practice. Those actions in turn lead to certain consequences latent within the realm of feedback & outcomes and presenting certain professional growth opportunities. These opportunities which can be harnessed and used within the stimulation and challenge domain to support teachers to engage and collaborate with each other in efforts of systematise and reflect on their own practice. The domain of stimulation and challenge draws not only from classroom outcomes and feedback but also from external expertise from peer engagements in the wider community of practice, which should serve to reinvigorate and stimulate deeper learning.

![The Enveloping Change Environment](image)

**Figure 1 The Learning for Teaching through Participation (LTtP) model (Nakedi, 2017)**

**The Aspects of Teachers’ PCK**
<table>
<thead>
<tr>
<th>PROFILES</th>
<th>DESCRIPTIONS</th>
<th>Views about NOS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Learners’ Prior Conceptions &amp; Positioning in Learning (LPC&amp;PinL)</strong></td>
<td><strong>Learners’ procedural Knowledge in Inquiry (LPKiai)</strong></td>
</tr>
<tr>
<td><strong>Didactic (Did)</strong></td>
<td>Teacher focus &amp; Pacing: Focus is on information transmission, structure, or sources rather than on the learners and the learning process itself. Pace guided by adopted curriculum or other school factors &amp; directed by teacher. Instructional Approach &amp; Assessment: Transmit the facts of science by presenting information generally through lectures and questions are used to cascade that students can reorganize the facts of science. Nature of Interaction &amp; Culture of Learning: Teacher provides information in a structured environment and learners are expected to pay attention, receive information from the teacher and take good notes etc.</td>
<td>Nature of Task: Learners participate in closed cookbook practical task (or teacher demonstrations) where everything about the task is prescribed and the task is used for verification. Teacher Facilitation: The selected activities are either conceptual lacking in coherence or if coherent the teacher might fail to understand their purpose and hence omit or inappropriately modify inbuilt aspects which are critical in promoting learners’ conceptual understanding or procedural knowledge.</td>
</tr>
<tr>
<td><strong>Level 1 Teacher-centred</strong></td>
<td><strong>Scientific knowledge is certain and not tentative</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Reform-based (Rbm)</strong></td>
<td>Teacher focus &amp; Pacing: Teachers’ focus is on mediating student knowledge or interactions and depends upon students’ responses to design an environment that allows for individualized learning. Pacing is based on ongoing evaluation which considers students’ abilities to demonstrate understanding in different ways. May involve modification of lessons. Instructional &amp; Assessment Approach: Uses various teaching techniques and suitable intervention to make meaningful bridges with the learners’ original views and new scientifically correct ones. Focus on mediating learners’ prior conceptions and the knowledge of the discipline. Use instructional strategies that value learners’ prior knowledge and promote strong and coherent understanding of concepts. Nature of Interaction &amp; Culture of Learning: Learners initiate significant interactions with one another and with the teacher about the topic. Teacher fosters intellectual rigor by engaging learners in activities that promote social discourse of critically attending to, defending and evaluating understandings.</td>
<td>Nature of Task: Learners are engaged in open inquiry tasks and design of their own investigation where variables are not specified but the problem for investigation could be specified. They are provided with opportunity to collect and process data, support competing theories or explanations as well as reflect on the quality of their design and make improvements. Teacher Facilitation: Learners’ questions or comments often determine the focus and direction of discourse. Teacher engage learners individually and in their collaborative groups to carry out a fully-fledged research task where in which they use the science concepts they learned in class to solve a specific problem or to address a specific need in their local community. In class, the learners use the collected data and findings to engage in argumentative discourse in forms of presentations and write-ups where they evaluate the connection between the claims they make and evidence.</td>
</tr>
<tr>
<td><strong>Level 5 Learner-centred</strong></td>
<td><strong>Science as a reflexive process and within community of practice where peer reviewing is a natural process of researching consensuses on what qualifies as scientific knowledge and what does not qualify</strong></td>
<td></td>
</tr>
</tbody>
</table>
Data pointed to the centrality of the teacher’s science subject matter knowledge (SMK) and its influence on other aspects of PCK to almost the same degree as the beliefs they hold about learning and teaching of science. Science SMK becomes the core of the knowledge and beliefs domain. This paper presents only three of the six aspects which have to do with how the teacher positions the learners in learning and the type of learning culture engendered through the nature of interactions promoted between the learners and the teacher and between learners themselves to promote science specific conceptual and procedural knowledge. These are the knowledge and beliefs of teachers about learners’ prior conceptions; about learners’ procedural knowledge and about learners’ socio-scientific reasoning (Sadler et al., 2007). Below is the LTtP Belief-Practice Cross Analysis Matrix which was developed to depict teachers’ changing epistemologies and approaches in practice into five profiles. Due to limitations of this paper only the first and the fifth levels are presented in figure 2 below.

The five profiles are: didactic (Did), instructive (Inst) which represents teacher-centred beliefs, transitional (Trans) which has a focus on behaviourist or affective attributes of students rather than cognitive, responsive (Rsp) and reform-based (Rfm), the last two of which are more learner-centred.

Conclusions

The paper presented a framework of profiling teacher learning environment as well as trajectories in developing capacity and PCK for socio-scientific literacy and science classrooms. The LTtP offers a coherent and synthesised tool for mapping and framing teacher change data in order to identify changing and varying structural patterns of professional growth efforts across various teacher case studies. Peer collaborative and reflective elements of self-study methodology, as well as the planning meta-cognitive tools such as the CoRe and structured journal format, led to improved meta-cognitive skills in planning teaching a controversial socio-scientific topic.

References:

Introduction

The fact that education is the vehicle through which every citizen can realize his or her potential and contribute to national development is no longer questioned. Malawi is one country that realizes this potential so that the vision of her education sector is ‘to be a catalyst for socio-economic development, industrial growth and an instrument for empowering the poor, the weak and the voiceless through provision of quality and relevant education’ (Government of Malawi, 2013). In order to achieve this vision, Government of Malawi recognizes that secondary education, beyond primary education, is critical as it provides additional knowledge, skills and attitudes crucial for enabling Malawians cope with the complex and sophisticated socio-economic and political environment of the global village to which it belongs.

In order to ensure achievement of the vision, the Malawi government reviewed her curriculum for secondary education. The rationale for the new curriculum, which started being implemented in the 2016/17 academic year, emphasizes on improving the responsiveness of the general population to the new problems being faced:

......the curriculum has put emphasis on practical skills that enable them (Malawian children) to achieve self-employment.

...It is also clear that a good secondary school curriculum enables a student to develop into an adult with sound intellectual, moral, physical, and emotional abilities. Therefore, the curriculum needs to address the whole range of students’ abilities and interests. In addition, it should aim at equipping the student to become an independent learner in order to promote personal, family, community and national development. The new curriculum has therefore been deliberately designed to achieve these important goals. (Government of Malawi, 2013, p v.)

Recognizing the many changes that the world and Malawi has gone through in the past century that has impacted on individuals, family, community and national development, this rationale is not only relevant but timely as well. Global issues of climate change, social inequality and environmental degradation are but examples of changes that have impacted Malawians. The question is how far has the curriculum indeed addressed such issues?
A curriculum usually contains many subjects. For Malawi, the science subjects occupy a central position since they are core subjects throughout secondary schooling. In the new curriculum, the science subjects were even extended so that there is separate Physics and Chemistry unlike the case before where the two were combined as Physical Science. How has the separation of the two sciences contributed to the achievement of the vision enabling the learners deal with the social challenges that they are faced with?

This paper reports the findings of a study conducted to explore whether or not the new Chemistry curriculum equips the learners with the purported knowledge and skills to cope with the complex and sophisticated socio-economic and political environment they are living in. The question is in what way is the new Chemistry curriculum promoting quality education where all become literate in relevant knowledge and skills that contribute to their understanding and mitigation of issues such as environmental degradation, climate change, social inequality and economic productivity?

**Conceptual framework**

The analysis of the new Chemistry curriculum in order to assess the extent to which it addresses the global challenges impacting on Malawians makes use of the P21’s Framework for 21st century learning. This Framework was developed with input from teachers, education experts, and business leaders to define and illustrate the skills and knowledge students need to succeed in work, life and citizenship, as well as the support systems necessary for 21st century learning outcomes. The Framework consists of student outcomes and support systems. One of the support systems is 21st century curriculum and instruction which is the focus of the analysis. The 21st century curriculum is expected to focus on:

- Teaching 21st century skills discretely in the context of both the key subjects and through 21st century interdisciplinary themes
- Providing opportunities for applying 21st century skills across content areas and for a competency-based approach to learning
- Fostering innovative learning methods that integrate the use of supportive technologies, inquiry- and problem-based approaches and higher order thinking skills
- The integration of community resources beyond school walls

The approach was to assess the extent to which the content in the Chemistry curriculum address 21st century skills and contributes to the global issues as well as the whether or not the learning methods being used promote inquiry.

**Methodology**

The study used a mixed methods design, combining a content analysis of the written curriculum through the syllabi, recommended student textbooks and teachers’ guides; and interviews with
Chemistry teachers and students. While the content analysis focused on the whole range of syllabi and textbooks for Form 1 through to Form 4, only teachers and students teaching Form 1 and 2 were interviewed. This is because the new curriculum has been taught in those classes only.

The subjects for the interviews were four chemistry teachers and their students from three secondary schools in Zomba district. The teachers had been involved in a community of practice where they were planning schemes of work and lesson plans together, while teaching at their own schools, and conducting joint reflection, including observing each other’s lessons. The community of practice enabled the teachers reflect more on the new curriculum.

Findings and implications

Preliminary findings from the content analysis show that the chemistry curriculum covers the whole range of chemistry concepts that a student would need to know for the 21st century, more than the previous syllabi where Physics and Chemistry were combined. This gives the students an opportunity to learn more about all chemical elements of their environment. The analysis however shows that competencies focus on knowledge, with minimal application to the everyday environment. The learning methods remain didactic, using chalk and talk with minimal integration of supportive technologies and inquiry based and problem based approaches, contrary to expectations of the 21st century curriculum and instruction requirements. The teaching approaches focus on the textbook so that much of the learning takes place only in the classroom. While teacher reflection of the new chemistry curriculum reflect an inquiry based approach in theory, in practice, their approaches lean on the didactic side. The implications of these findings will be discussed once the full analysis is concluded.

References

TEACHING STRATEGIES TO ENHANCE LEARNING OF NATURAL SCIENCES
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Abstract
This paper explores teaching strategies that science teachers may integrate when teaching science concepts. This is done through a) reviewing philosophies relevant to the teaching of Natural Sciences, b) providing scenarios relevant to the mystery of science concepts. In this paper, the authors argue that the learning of Natural Sciences is not as smooth as it might seem from the outside. There is no way science can be taught and learnt in a frictionless environment. What happens is that most students get absorbed in the system, and during the course of their studies, they experience major set-backs. Others might proceed due to the capital they have, which enables them to adjust in the new environment, while others might get trapped in the spiral. Thus, some might withdraw under the circumstances. Here, the authors share their views on how to assist students that are trapped in the web to minimise the risk of their being side-lined. As science education teachers, sometimes we do not realise our agency (roles, responsibilities and identities) and sources in our communities, which should be used in teaching and learning. It is against this backdrop that we want to share ideas on how to address bottlenecks faced by students when they learn science. The Cultural Historical Activity Theory (CHAT) underpins how Natural Science Education is taught and learnt here. The theoretical underpinning and recommendations of affordances for teaching and learning are discussed as well.

Key concepts: threshold concepts bottle necks, teaching and learning, Indigenous Knowledge Systems

Introduction
This paper explores the teaching strategies that are applicable in helping demystify abstract science concepts. According to Hedegaard (2004), it is not only through classroom social practice that learners conceptualise science concepts, it is also through different knowledge, motives and personality integration that learning is influenced, and that a particular learning form is brought into the classroom and thus contributes to their own learning. Thus, strategies that could be used to address challenges that students encounter in conceptualising science concepts are discussed. The value of IKS in addressing such difficulties is explored as well. Learning in school has traditionally been transmitted by a teacher to the learners. However, in the modern world, mediated learning is prevalent. This has become the way of getting knowledge across to learners, thus social activities and knowledge forms prevail. This paper is framed in Cultural and Historical Approach learning. Here, it
is stressed that children already have knowledge of certain concepts when they enter the classroom, and the teacher (the knowledgeable other) is seen as the mediator of their learning (Vygotsky, 1978)

**Literature review**

Killen (2010:23) describes learning as ‘a process that involves making connections, identifying patterns, and organising previously unrelated bits of knowledge, behaviour and actions into new patterned wholes’.

Bamber and Anderson (2011) add that learning ‘is change in understanding and behaviour that results from encountering new experience’. I view learning as involving a process of planning and implementing a learning experience, as well as assessing learner achievement from the planned learning experiences. Stewart (2015) defines learning as the acquisition of new knowledge, skills, values and/or attitudes because of instruction, study, experience or intuition – leading to the modified understanding or action. From these definitions, one can deduce that learning involves:

- A process that is based on a theory which leads to actions;
- Changes, attitude, behaviour and understanding because of modified experiences, which are sometimes based on the pre-existing experiences and the means of socialisation.

The above definitions are themselves dependent on one’s ontological orientation in the context of the three theoretical perspectives, vis; behaviourism, cognitivism and constructivism. It could be argued that as we learn, we alter the ways in which we perceive our environment and apply ourselves to it. The way we interpret events and processes taking place in our environment; and the way we process incoming stimuli – and, therefore, how we interact with others or behave towards them. There are also notions of social versus asocial learning, where social learning refers to learning that is influenced by observation of or interaction with another person (external view). Asocial learning is regarded as a change in a person that is caused by a specific experience at a certain time (Young, 2008).

Teaching involves a process of planning and subjecting students to experiences that could lead to their attaining new knowledge, understanding, competences, skills, values and/or attitudes – including even their ways of interpreting their environments, looking for meanings and understanding (Biggs, 2012; Black and William, 2012; Bernstein, 2000). Inevitably, within the requirements of the school system, teaching also involves learner assessment. That is, measuring and evaluating student achievements from the planned learning experiences.

When students enter the higher education system, they bring with them different backgrounds, experiences, expectations about learning, self-perceptions and a sense of belonging. Learning is a social as well as an individual process. To enhance student learning, attention should be given to the
social context in which learning takes place (D'Andrea & Gosling, 2005). Reflecting on D'Andrea & Gosling’s (2005:52) study about student needs, I realise that learning occurs through participation in social practices in which meaning is constructed and negotiated, and identities formed and re-shaped.

Northedge (2003) argued that as universities become more diverse, this poses a challenge to teaching and learning. A knowledge delivery and surface approach to learning is no longer sufficient (Barr & Tagg, 1995). Students look for a more structured and engaging learning experience where they can actively participate in an unfamiliar knowledge community’s discourse (Barr & Tagg, 1995). In order to create a learning environment where students understand and critically engage with learning processes, it is my responsibility as a teacher to provide a learning space where students are able to critique my teaching through evaluation. Also, I should follow a teaching approach that enables them to reflect on their learning. Northedge (2003) attest to the fact that students sometimes struggle to find their voice and academic identity within a specific discourse. Teaching should support students and provide them with opportunities to participate through writing, speaking and thinking in the language of the community discourse.

Adopting a socio-cultural approach to teaching and learning allows teachers to create opportunities that make it possible for students to become increasingly competent in this knowledge community as the users of the specialised discourse and as participants therein. Within the learning environment, various ways of ensuring epistemological growth must be created. But, the challenge lies in creating a student-centred learning environment where the students’ diverse learning needs can be accommodated and addressed. The examples of creating learning spaces include academic literacies, IKS and information technology. Above all, one has to understand the teaching and learning philosophies and the technological systems such as e-learning. The following IKS application can demystify abstract science concepts. Opened up spaces for my students to demystify concepts leads to their epistemological access to science.

Theoretical framework

This paper’s theoretical framework constitutes the vertex of the constructivist theory, referred to as the Cultural Historical Activity Theory (CHAT). CHAT emerged from the Russian social-psychology in the 1920s, through Vygotsky (1978) describes the relationship between “subjects” (people, groups), “tools” (concepts, technologies), and “objects” as purposeful group activities. Initially, Vygotsky (1978) was interested in an individual’s cognitive development (Gretschen, Ramugondo & Galvaan, 2015), for example, how people use tools to complete tasks or objects of work. Engeström outlined the activity system model in 1987. Both Blackler and he articulated how networks of activities influenced each other through the 1990s. (Gretschen, et al, 2015) In South Africa’s context, CHAT is key in the integration of IKS into the curriculum because of the country’s cultural diversity, where each culture has its unique way of imparting knowledge to the children’s developing minds. Many of these take this knowledge to school where they are introduced to a curriculum that is different from
what they have been taught in their homes and communities. This concurs with what Moyo (2017) refers to as “the suppression of their knowledge so as to accommodate the newly learned western knowledge”.

The curriculum knowledge is further decontextualised during teaching practice. One of the main insights with regard to the teaching and learning field relates to the ways in which students are inducted into the educational discipline domain. Gee (2007) argues that this is best achieved through an academic ‘apprenticeship’, where disciplinary experts explicitly model good disciplinary practice. This implies that students are gradually inducted into a disciplinary community by being actively engaged in the learning process via a range of curriculum processes and discourses in higher education that eventually translates into teaching and learning.

Research methodology

This was a critical literature study based on the analysis of different authors’ views on the The factors that contribute to the success of teaching and learning of Natural Sciences (NS). Typically, a critical literature study provides an up-to-date critical review of what is currently known about the subject of interest, and offers some insights into the teaching of Natural Sciences as a subject. The search of the literature provided an insight on how students learn NS and our role as teachers to provide the students with capital to adjust with the higher cognition of science concepts.

Results

Findings from the literature are presented in various sections below.

Using indigenous knowledge to create opportunities for understanding Natural Sciences concepts

CHAT implies that cultural knowledge is continuously revealed as open and expanding to integrate the home experience and the science curricula in demystifying the abstract scientific concepts. This is illustrated through enzyme reaction in (Table 1.1), one of the threshold concepts in Natural Sciences. Meyer & Land (2003:165) define threshold concepts as “the conceptual space entered and occupied by higher education students” that experience difficulty “during their programmes of learning”. These concepts are unique in a discipline and are most likely to become bottlenecks. The teacher should, therefore, recognise the importance of engaging with science concepts.

Table 1.1: Teaching strategy that integrates indigenous knowledge and science, adapted from Mukwambo, Ngcoza and Kundanda (2014)

<table>
<thead>
<tr>
<th>Science Teaching in classroom</th>
<th>Knowledge from home experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enzymes and Germination</td>
<td>Making of fermented sorghum porridge (umncindo)</td>
</tr>
</tbody>
</table>
Germination stimulates enzymes that digest starch (amylases, including maltase) in the seed to digest the starchy part of the seed (endosperm).

<table>
<thead>
<tr>
<th>Germination stopped by drying the seeds but the enzymes are not harmed</th>
<th>Drying of germinating seeds (at a specific stage of germination)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grinding increased surface area for enzymes to leave the malt grains</td>
<td>Grinding of dried germinating seeds with grinding stone</td>
</tr>
<tr>
<td>If malt is added while the porridge is too hot, maltase from the grinded malt can be denatured</td>
<td>Mixed with warm porridge (cooked grain porridge; not too hot/hot) and left to stand</td>
</tr>
<tr>
<td>To speed up/catalyse the reaction</td>
<td>Warmth provided</td>
</tr>
<tr>
<td>Enzymes from malt digest cooked starch in sorghum porridge to sweet maltose.</td>
<td>Starch + amylase – Maltose (the most abundant sweet sugar makes the sorghum porridge to taste sweet)</td>
</tr>
</tbody>
</table>

Here, the home experience is regarded as a first space, the science classroom is the second and the IK is the third space for exploring the science curriculum. Orgunnyi (2004) argues that IKS should be the first space considering that its knowledge emerges from home experience. To him, IKS should come first, followed by science knowledge in the classroom. Those who advocate for the use of IKS as a third space argue that the understanding of scientific concepts occurs in a science classroom. In Table 1.1, one can integrate home experience with the teaching and learning of enzymes reaction. A teacher could probe at each stage of the enzyme reaction through themes such as discussing the factors that affect the rate of chemical reaction. For example, one can ask students to predict the next stage in this reaction. From the Third Space theory by Bhabha (1994), one realises that students have relevant home science they bring into the classroom, and hence IKS can be used as a platform to offer such opportunities.

While the inclusion of home experience can be integrated in Natural Sciences, there is a challenge in accommodating diversity. For instance, this approach can be effective for students of the Nguni group who understand the processes of making traditional porridge. Students from other ethnic backgrounds, including Indians, Whites, Batswana and Pedi, have no idea of what sorghum porridge fermentation is. This means that while IKS enables learning (Orgunnyi, 2004–2011; Mukwambo et al., 2004; Odora-Hoppers, 2002.) when integrated in science education, the issue of context is important. This calls for a teaching strategy that recognises that learning is a process that is embedded in culture and philosophy. In this case, social constructivism can interplay, while learners may be introduced to a peer teaching learning strategy. This can be through peer learning discussions on the matter, and allow students to share their experiences in this regard. I intended to mix students who are familiar with the concept with those who are not.

In addition to the example in Table 1.1, there are opportunities to cater for diversity when defining threshold concept in their vernacular. For instance, when dealing with concepts on conservation, the students have to define these in vernacular. For example, in isiZulu, the concept is ukulondoloza (care), in isiSwati ukulondolotan (almost the same as Zulu since both belong to the Nguni language...
family), in Nigerian Igbo nchekwa, in Sotho, ho sireletsa, and in Afrikaans bewaring. We shared these concepts with my students and I verified them through Google translator. Thereafter, the authors drew examples from the Natural Sciences’ definition of conservation. One way of doing this is through the use of Legitimate Code Theory. This is discussed hereunder.

**Ways of knowing in Science Education**

In writing about the legitimate code theory, Clarence (2016) states that educational practice is usually oriented towards something (= knowledge) and/or someone (= knower) and conventional wisdom, science has a knowledge code. In other words, enabling epistemological access is complex, it takes into account;

- Knowledge and knower codes (even in sciences); and
- Epistemic-context access and learning-context access.

Ontology becomes evident when spaces of support are not created. This results in code clashes (when either the science knower-science teacher or science learner are not complementary). This means that there should be spaces to support science knower-disciplinary content and literacies with the learners’ science learning context. This theory assists me to understand my role as a science teacher. In considering the third space theory to create epistemological access to my students and the legitimate code theory, the authors became familiar with Bernstein’s (2000) pedagogical orientation.

Bernstein (1999) distinguishes between vertically and hierarchically structured knowledge. The former, which Maton (2007) refers to as the ‘epistemic relation’, is typically dominant in the sciences where the knowledge itself and the possession of decontextualised, specialised knowledge and skills are emphasised. The latter, which frequently characterises the Humanities and Social Sciences, is referred to by Maton as the ‘social relation’, is a context-dependent knowledge, which focuses more on the identities and dispositions of the knowers as a way of measuring success and less on the possession of specialised knowledge (Maton, 2007). Although one relation or curriculum type is dominant, however, the two aspects are not mutually exclusive and all curricula should be viewed as a combination of both. Within this, Bernstein’s concept of the ‘pedagogic device’ is central and is used here to structure the theoretical framework and to provide an understanding of how academic access to knowledge through curriculum development is.

The nature of knowledge in science differs from the education discipline. Maton (2007:49) differentiates between knowledge structures in the science and humanities thus,

> A series of specialised languages, each with its own specialised modes of interrogation and specialised criteria with non-comparable principles of description based on different, often opposed, assumptions, whereas in pure discipline knowledge is ‘an explicit, coherent, systematically principled, hierarchical organised, and develops through integrating knowledge at lower levels, and across an expanding range of phenomena.
I used the Legitimate Code Theory (LCT) by Karl Maton (2007) to integrate the practice (discipline) and to understand the values held in the two disciplines. Clarence (2016) differentiates the nature of disciplinary knowledge in science and education by stating that educational practice is usually oriented towards something (= knowledge) and/or someone (= knower, for instance students) and conventional wisdom. In other words, enabling epistemological access is complex. It takes into account the knowledge codes and knower codes and epistemic-context access and learning-context access. I concur with these in that even in sciences, the nature of knowledge requires a knower and how to code the discipline in terms of academic literacy. The teacher’s role is to enable a learning-context access whether in science or in education by teaching them the literacies relevant for their disciplines.

Using the pedagogic device as a broad framework, a number of key concepts that can be mapped onto each of the fields were identified. These concepts shape the selection of knowledge and skills from the field in which they were developed and inform the way in which they are decontextualised in the process of curriculum development and reproduced in the pedagogical context (Wheelahan, 2010). While considering the Bernstein’s (2000) model, it is imperative to consider the nature of my teaching philosophy to lens how students learn.

**Philosophical views of how students learn**

There are various philosophies that underpin students learning. As teachers sometimes, we know how we learn, but do not necessarily consider how our students learn, nor do we consider the way in which we teach these to enable learning (Fry, Ketteridge & Marshall, 2009). Students experience difficulties in their learning, and learning does not always occur as the teacher wishes (Middendorf & Pace, 2004). It is vital to understand how students learn so that necessary scaffolding is provided to address bottlenecks when assimilating science concepts. At this juncture, it is important to draw from mediation, behaviourism, cognitivism and constructivism teaching and learning theories (Figure 1.1).

Some students are able to proceed, some got stacked and some sink back here

*Figure 1.1: Theoretical view of how learning takes place.*
With reference to Figure 1.1, it is expected that all students can proceed, yet it is not often the case. Some students have problems that become bottlenecks, and hence are not able to proceed with learning. Other students experience ‘cognitive conflict’ (contradictions/discomfort that occur as a result of previous knowledge when students experience new scientific concepts). Students get confused in such a way that they tend to forget everything new and what they used to know before being taught new scientific concepts. The teacher’s role is to devise interventions to address bottlenecks.

In exploring teaching and learning ideas by Andrew Northedge (2003), it is considered that social environment (home, church, society, and peer experience) plays a critical role in learning. That is, social context affects learning and cognition and can contribute to a gap in science knowledge. In reinforcing my social constructivism, Table 1.1 is applicable here.

To address bottlenecks through the use of behaviourism, a recognition of learning as occurring through behaviour change is vital. In Vygotsky’s dog experiment, it was discovered that positive (rewards) reinforcement leads to behaviour change. If animals do not want to continue with behaviour, negative reinforcement (punishment) is reinforced (Stewart, 2015). Regarding the former, it results in students progressing to the next level, while the latter may result in students stacked along the way or withdrawing during the teaching and learning process (Figure 1.1). My role here is to recognise that students are human beings and they attend lectures with resource, social and cultural baggage. The school of thought in this case is the use of a tool to demystify abstract scientific knowledge.

**Scholarly view of teaching and learning**

In the classroom, when students are asked to work in groups and discuss a matter, one of the requirements for using the ‘discussion’ instructional approach is that there should be a controversial topic on which different people would normally have different opinions. Typically, these diverse opinions arise out of people having different personal experiences, which result in the different interpretations of the same events (Gagne, 1977). This means that different people operate from different internal realities, and these are personal even when they are socially constructed – i.e. arising out of interactions with other people. Thus, one could argue that even when people have agreed about something, their individual mental representations of what they have agreed upon may not be identical because each processes new information in his or her own way. This is due to the underlying variations in learning and processing mechanisms of different individuals.

Jonassen’s observation that ‘constructivism does not preclude the existence of an external reality, but merely claims that each of us construct our own reality through interpreting perceptual experiences of the external world’, means that there is, in effect, more agreement than argument on this matter (Jonassen, 1991: 7). This observation allows us to start building bridges between objectivism and constructivism. Certainly, it would not be logical to argue that there is no reality
(objective or otherwise), which is external to the individual, just as it would not be logical to argue that individuals do not have their own personal internal realities. Therefore, the task before us is one of aligning these realities (external and internal) with each other, wherever possible, so that we eliminate or reduce whatever cognitive disparities and dissonances that may exist between them. It then follows that this is where understanding the internal individual mental processes (cognitivism) that pertain to a given task, could assist the constructivist teacher bridge the conceptual gap learners may have.

One way to do so would be to give direct instruction (behaviourism), where the learner’s internal processes suggest a lack of the necessary background knowledge, and it appears unlikely that the learner would benefit from social interaction with peers, experts and others, when he or she lacks the necessary background knowledge. In such circumstances, the learner in question may fail to construct his or her own understanding of the phenomenon concerned based on his or her interaction with the physical or social environment (constructivism). Vygotsky (1978) points out key points on learning science as the social construction of knowledge. For example, learning is the process by which individuals are introduced to a culture by members that are more skilled. In this way, for learning to take place, there should be a knower and a learner. This suggest that as teachers, we need to support our students to learn. When students learn, they assimilate (make meaning of the new information). Assimilation happens when students use existing concepts to deal with new phenomena, the integration of a new concepts into existing cognitive structure (Vygotsky, 1978). Once information has been assimilated, it is then accommodated in the minds of students. Accommodation happens when existing concepts are inadequate to grasp some new phenomenon successfully. Then, the student must replace or reorganise his central concepts.

This is a more radical form of conceptual change. With these theories in mind, the authors of this paper point out the three main processes that occur when students learn. Knowledge and understanding is constructed when individuals engage socially in talk and activity about shared problems. However, learning does not always occur as intended (Figure 1.1). Inevitably, within the requirements of the school system, teaching also involves learner assessment. That is, measuring and evaluating student achievements from the planned learning experiences. To be successful in ensuring that learning takes place optimally, as teachers, we usually plan and implement their lessons under the influence of one of the above three educational psychological perspectives.

**Conclusion**

One of the difficulties African learners face in learning science is that the subject is very decontextualised and alienated from what they know. However, science provides our lives with so much such that every citizen has to be scientifically literate. This should be the government’s central aim for all citizens. The onus is, therefore, on the teachers to help learners to appreciate the roles of both scientific knowledge in our society. In summarising the metaphysical assumptions of objectivism
based on the philosophies and practices of science teachers, Jonassen (1991: 59) points out that the important metaphysical position that objectivism makes is that ‘the world is real, that it is structured, and that its structure can be modelled for the learner’. The authors of this paper share the same sentiments that in their review that that learners actively construct their own sets of meanings and understandings; knowledge is not a mere copy of the external world, nor is knowledge acquired by passive absorption or by simple transference from one person (educator) to another (a learner or knower). What is recommended is that we as teachers need to understand the nature of Natural Sciences learning and devise strategies that can loosen up bottle necks that can be experienced by students in learning science concepts. One of the ways of closing the loop with the content and context is through integrating the philosophical views of learning in the school curriculum which provides an opportunity for the involvement of indigenous knowledge communities in some school activities.

References


EXAMINING TOPIC SPECIFIC PEDAGOGICAL CONTENT KNOWLEDGE WITHIN THE ASSESSMENT PRACTICES IN THE SOUTH AFRICAN NATIONAL SENIOR CERTIFICATE EXAMINATIONS

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Introduction

The purpose of this snapshot paper is to elicit ideas and reviews of the proposed study to explore PCK in relation to South African National Assessment for the Senior Certificate. In South Africa, the revised framework (MRTEQ) for preparation of prospective teachers refers to Pedagogical Content Knowledge as one of the pedagogies to be developed. On the other hand, policy such as the National Curriculum and Assessment Policy Statement (CAPS) outlines the nature and purposes of Secondary school subjects. This, policy guides the philosophy supporting the teaching and assessment of subjects, particularly at Grade 12 as a point of administration of a national examination. To strengthen the implementation of CAPS, additional policy documents such as the Examination Guideline provides clarity on the depth and scope of the content to be taught and assessed in a specific grade as well as at the Grade 12 National Senior Certificate (NSC) Examinations (DBE, 2017). Both the PCK as knowledge for teaching, and the content to be taught in Secondary School science are a competancy explicit in the education policy framework.

In science education, Initial Teacher Education has embraced and implement PCK, particularly at topic level (TSPCK), as the professional knowledge for pre-service teacher preparation (Mavhunga & Rollnick, 2017). TSPCK is defined as the teacher knowledge needed to transform abstract content knowledge through the interaction of content specific PCK components. Thus, for a specific topic, good quality of teaching is evident when a teacher pedagogically reasons through these components in a highly sophisticated manner during lesson planning and teaching.

In this study, we therefore argue that if good TSPCK in topics covered by the CAPS is acquired, it would inherently reveal teacher’s understanding of the fundamental aspects espoused in the policy. By this we mean, teachers with good TSPCK are better positioned to know the depth and scope of the content knowledge that must be taught and assessed across specific grades, the sequencing of the main concepts in a topic, prior knowledge needed and what representations are most appropriate. All these are aspects that are strongly linked to TSPCK knowledge components. This postulate does not mean teachers exposed to TSPCK need not consult the policy statements, but they would be comfortable and able to implement the policy stipulations with pedagogically reasoned
justification. In turn, their teaching would help to prepare their learners for successful achievement in the NSC Examination.

Problem Statement

The Organisation for Economic Co-operation and Development in 2015 revealed that South Africa ranked 75th out of 76 countries surveyed. This survey highlighted the poor quality of mathematics and science teaching, and learner achievement in local and internationally based assessments, the same concern raised by the Centre for Risk Analysis (CRA, 2018). Many initiatives to mitigate this scourge exist. An example of a relatively new initiative at teacher preparation level, in science education, is the teaching of PCK to prospective teachers in one specific topic at a time as TSPCK. This approach has been shown to develop the knowledge for teaching the intervention topics and new topics for learner understanding. However, what is yet to be establish is the proven alignment across the kind of assessment tasks contained in the NSC Examination, to the teachers’ TSPCK, where TSPCK is currently defined from the transformation of content knowledge using the five content specific components.

Main question:
How is TSPCK appropriate, if at all, in preparing learners for successfully completing the assessment tasks in Organic Chemistry in the National Senior Certificate examination?

The following sub-questions are suggested in eliciting responses towards the main research question.

1. What is the nature of correlation between the assessments tasks in organic chemistry contained in the last five year’s National Senior Certificate Examinations and the curriculum policy guidelines.
2. How does the observed nature relate to learner performance trends in organic chemistry nationally and within the D-12 district in Soweto?
3. How do the established correlation in (1) and the learners’ performance trends (2) relate respectively, to the quality of collective TSPCK in planning and personal TSPCK in classroom enactment of the Grade 12 physical science teachers in the D-12 district in Soweto?

Research Design

The study is structured in two stages. Firstly, a content analysis of various elements of CAPS on organic chemistry in the last five years and learner performance trends in chemistry at both National and District-12 level. The content will be analysed for correlations and non-correlations. The second stage entails the observed correlations with the quality of TSPCK in organic chemistry of teachers in the District-12. For this stage, a mixed method design within a case study approach will be employed. A sample of ten practicing teachers will be selected. They will be exposed to an intervention, targeting to improve the quality of their TSPCK in organic chemistry. Data to measure the quality of their TSPCK in planning to teach and in teaching organic chemistry will be collected before and after the
intervention. Also collected will be learner achievement data on assessment tasks in organic chemistry extracted from the NSC examinations mentioned in stage 1. The learner performance data will be collected before and after each lesson.

Analysis will focus on correlations and incongruence between the quality of teachers’ TSPCK, nature of assessment tasks and the learner achievement. Data triangulation will enhance trustworthiness, Rasch will be used to establish validity of quantitative learner achievement scores. Clearance certificate will be applied from GDE and the University. The participants identity will remain anonymous.

References

South African Indigenous Knowledge in High School Biotechnology

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Abstract
The effects of inclusion of South African indigenous knowledge examples in teaching High School biotechnology concepts were investigated. Four hundred and four (404) learners in intact groups from six schools in Mpumalanga province participated in the study. A teacher-training manual was developed to assist teachers in using indigenous knowledge when teaching biotechnology concepts. Quasi-experimental non-equivalent post-test control and experimental group design was used to guide the collection of quantitative data. The experimental group was taught biotechnology concepts using examples from indigenous knowledge while the control group did not receive any treatment. Both groups wrote a researcher-made achievement test. Results showed that experimental group (M=13.69, SD=6.242) achieved significantly higher scores (t=10.018, df=382.75), the two tail (p=0.000) than the control group (M=7.72, SD=5.729), which is a large effect size (η²=0.199). Topics on the function of microbes were too abstract for the learners’ conceptions and the learners were unable to answer higher order questions.

Keywords: biotechnology, Indigenous knowledge, indigenous learner, western knowledge.

1 INTRODUCTION

There have been rapid developments in biotechnology in the last century. Researchers believe that a high level of scientific literacy can help young people to question the claims of the scientific community and enable them to use their understanding of science to make well-informed ethical decisions concerning biotechnology (Atagana, 2009; Dawson & Schibeci, 2003). However, while biotechnology is promising to be beneficial to the sustainability of growing populations, a number of studies have shown that learners have low knowledge levels about this technology (Atagana, 2009; Cavanagh, Hood, & Wilkinson, 2005; Dawson, 2007; Department of Basic Education, 2012 & Harms, 2002).

Studies conducted in South Africa have emphasized a lack of biotechnology knowledge by some learners. Fifty five percent (55%) of the subjects in the study carried out in South Africa claimed to know biotechnology (Atagana, 2009). However, only 35% of these subjects correctly gave an example of biotechnology. Atagana (2009) concluded from his study that despite learners having good understanding of basic concepts fundamental for the learning of biotechnology concepts, this knowledge did not transfer successfully to understanding biotechnology and genetic engineering. He
highlighted that learners failed to make distinctions between biotechnology concepts such as cloning, genetically modified foods and foods produced by other biological processes.

Basu and Barton (2007) support the proposition of considered difficulties of learners by indicating that traditional curricula with shortcomings still exist in most countries, which still view science mainly as a large body of authoritative and unquestionable knowledge. As a result, they concluded that learners may become disengaged from school science if their culture and local knowledge are not incorporated into the science curriculum.

Another reason for difficulties experienced by learners when biotechnology concepts are tested is that, until now, curriculum planners have paid more attention to policy changes driven by politics rather than changes that focus on learners’ difficulties and sound curriculum planning (Feza, 2014; Maluleka, Wilkinson & Gumbo, 2006; Masemula, 2013). The result of these studies have indicated that while the National Curriculum Statement speaks of valuing indigenous knowledge and mentions the word “integration”, there was no evidence of any practical integration (Masemula, 2013).

It is against this background that the researcher found it of paramount importance to conduct this study. Researcher aimed to find ways of teaching biotechnology concepts in a way that would assist the learners to understand scientific concepts better and perhaps lead to improvements of scores when biotechnology concepts are tested. The researcher was motivated to conduct this research by low achievement in biotechnology concepts not only of learners in South Africa (Atagana, 2009) but also internationally in countries such as Australia (Cavanagh et al., 2005; Dawson, 2007; Steel & Aubusson, 2004), Turkey (Usak, Erdogan, Prokap, & Ozel, 2009), Slovakia (Prokop, Leskova, Kubratko, & Diran, 2007) and Taiwan (Chen & Raffin, 1999). Further, motivation to carry out the study was provided in response to the failure of curriculum planners to clarify how indigenous knowledge is to be integrated in the teaching of scientific concepts. The researcher developed a conceptual framework that helps to integrate indigenous knowledge into the science curriculum. Details of this conceptual framework are discussed in more detail in the following subsections.

Fakudze (2004) explored how the learning of science concepts takes place within a traditional socio-cultural environment, she suggested the need for development of instructional strategies that would help teachers to present science in a way that would take into account the learners’ indigenous knowledge and cultural beliefs. The researcher consequently developed teaching and learning materials and lesson plans that integrated learners’ knowledge and cultural beliefs.

It is believed that the inclusion of indigenous knowledge examples could be useful to the teachers in the teaching of some biotechnology concepts such as cellular respiration or fermentation used in traditional beer (umqombothi) brewing.

2 BIOTECHNOLOGY, INDIGENOUS KNOWLEDGE AND SCIENTIFIC KNOWLEDGE
2.1 Biotechnology
Biotechnology involves processes which use organisms or their components, such as enzymes, to make products that include wine, cheese, beer and yoghurt (Human Genome Project Information, 2008). Firdaus-Raih et al. (2005) suggest that biotechnology is a broad field. There are two very different but interrelated areas. On one hand, there is classical biotechnology. Two common examples of classical biotechnology are fermentation and breeding by genetic selection. On the other hand, there is modern biotechnology that takes into account the molecular systems that are involved in biology. These systems primarily cover recombinant DNA technology and its applications (Firdaus-Raih et al. 2005). They further indicate that classical biotechnology may have been around for thousands of years but is still relevant in this day and age. They suggest that, both technologies can work hand in hand, to provide better quality of life for current and future generations.

2.2 Indigenous knowledge
Indigenous knowledge (IK) may sometimes be referred to, among other terms, as traditional ecological knowledge; local knowledge; rural peoples’ knowledge or farmers’ knowledge; ethnobiology or ethnoscientific; folk science; indigenous science; traditional knowledge and local knowledge (Abejuela, 2007). IK refers to the long-lasting information, wisdom, traditions and practices of certain indigenous peoples or local communities, which have been passed on orally from person to person for generations (Rohandi & Zain, 2011). Indigenous knowledge is thus wide-ranging; in that it covers all technologies and practices that have been, and are still being, used by indigenous people in their everyday existence (Dziva, Mpopfu, & Kusure (2011). IK is oral knowledge; involving appropriate inter-generation living transmission in the form of stories, riddles, games, songs, dances, rituals, ceremonies, dreams, and intuitions (Hewson, 2014). Apart from indigenous knowledge being transmitted orally, it may also be acquired through direct experience in the natural world (Barnhardt & Kawagley, 2005). IK is often seen to exist in a local context, anchored to a particular social group, in a particular setting at a particular time (Agriwal, 1995). IK can be defined as the sum of experience and knowledge of a given ethnic group that forms the basis for decision-making in the face of familiar and unfamiliar problems and challenges (Warren & Cashman, 2003).

2.3 Western Science
Scientific knowledge is derived from scientifically controlled experiments, conducted in formal learning institutions (Strydom, Ferreira, & Hanks, 2012). Scientific knowledge has other co-terms, such as western science (Battiste, 2002; Strydom et al, 2012), Eurocentric knowledge or modern knowledge (Battiste, 2002). Western knowledge is a general word for the dominant knowledge system of the western world that originated in Europe (Hewson, 2014). Hewson argues that around the world; western knowledge, values and skills dominate those of indigenous peoples. Barnardt and Kawagley (2005) further suggest that western science education tends to emphasize compartmentalized knowledge. This kind of knowledge is often taught in the detached setting of a classroom or laboratory. Continuing with the definition of western science, Agriwal (1995) argues that western science education tends to ignore the social, political and cultural contexts in which it is implemented.
3 PEDAGOGIES USED FOR THE TEACHING OF SCIENTIFIC CONCEPTS.

While teachers acknowledged the importance of integrating indigenous knowledge in education, the lack of ideas on how to integrate it in the classroom hindered effective inclusion of IK in education (Cronje, De Beer, & Ankiewicz (2014). Furthermore, Lestekha, Wiebesiek-Pienaar, and Meyiwa (2014) highlight that a lot of schools in South Africa are unable to take advantage of the opportunities created by the National Curriculum to adapt specified knowledge to local conditions or incorporate local knowledge into the curriculum due to the limited resources available to them and lack of knowledge on how to do so. Therefore, it was paramount to explore pedagogies that could be employed by teachers in order to implement indigenous knowledge in the classroom. A variety of instructional strategies may be needed, five of which are discussed below.

The first instructional method is border crossing (suggested by Jegede & Aikenhead, 1999; in Cronje et al., 2014). In this strategy, learners cross border lines as they travel from their everyday life-world into the world of science. As a result, this method involves collateral learning as two knowledge systems are learnt simultaneously. Cultural border crossing depends heavily on how the learners perceive the cultural divide, and the teacher's assistance. Fakudze (2004) also suggested a cultural border crossing curriculum like that of Jegede and Aikenhead (1999). She proposed a curriculum that crosses the boundary between the learners' worldview and the scientific worldview. The suggested curriculum approach requires teachers to understand the learners' fundamental, culturally based beliefs in order to teach the kind of science that coincides with the intellectual interest and sociocultural setting of such learners (Fakudze, 2004).

The second instructional method involves indigenous education practices whereby indigenous knowledge is moved from the periphery to the centre of the learning process (Barnhardt & Kawagley, 2005; in Cronje et al., 2014). Lessons can be constructed around observing the natural processes occurring in indigenous or local settings, collecting evidence, testing the evidence, communicating results and verifying ideas. However, the challenge here is that the teachers do not always have the necessary knowledge of the indigenous sources and practices (Cronje et al. 2014). Barnhardt and Kawagley (2005) suggest that scientific inquiry should be linked with indigenous educational methods. Scientific as well as indigenous inquiry can harmonize each other as both suggest observation and study of the natural world, collecting evidence, testing the evidence, communicating results and verifying ideas (Cronje et al. 2014).

Contiguity argumentation theory proposed by Kwofi and Ogunniyi (2011) as in Cronje et al. (2014) is the third instructional method. In this type of instruction, the learner and the teacher argue and debate on issues relating to the nature of science. Benefits of this method are that teachers learn from the learners, while learners also learn from the teacher. However, contiguity argumentation theory can be hampered by a lack of language skills among learners, lack of prior knowledge, and time constraints (Cronje et al., 2014). Cronje et al., (2014) point out that the contiguity argumentation
method is built on Eurocentric types of argument. As a result, they agree that most learners would fail to argue their ideas out.

The fourth instructional method highlighted, suggested by Lemke (1990) and described by Cronje et al. (2014), is termed scientific enquiry and science investigation. Scientific inquiry involves studying the natural world, asking questions and posing ideas, collecting evidence to justify assertions and explanations, and communicating results (Cronje et al., 2014). Scientific inquiry tends to be divorced from learners’ everyday activities. Therefore, connecting the practices of scientific discourse and inquiry to learners’ everyday discourse can help support learners’ learning of scientific inquiry. However, Lemke (1990) argues that the norms of scientific discussion, which are common throughout written scientific texts as well as in science classrooms, contribute to the mystique of science. Science is seen as difficult, authoritative, and objective.

In addition to the four suggestions on instructional methods described by Cronje et al. (2014), De Sā Freire, Xavier, & Moraes, (2003) investigated using lectures as a fifth instructional method. However, the results of their study in Brazil indicated that the lecture method did not work as this method left the learners in the study with only a superficial notion of biotechnological concepts. They proposed that learners would assimilate concepts better when issues are discussed instead of being explained (De Sā Freire et al., 2013). While lecture method was suggested as the fifth method of teaching, it was not considered for this current study as it was proved to be a hindrance to learning.

4 CONCEPTUAL FRAMEWORK

A conceptual framework involves, among other aspects, seeking conceptual meanings for terms and concepts that will underlie the study. Cohen, Manion, & Morrison, (2011) say that concepts enable researchers to impose some sort of meaning on the world. Conceptual frameworks enable researchers to impose some sense, coherence and order on reality. Cohen et al. further indicate that conceptual frameworks help researchers to come to terms with everyday experiences and to shape their perceptions of the world in a particular way. Thus, through a conceptual framework, researchers can form a wider meaning system, which permits them to give an account of that reality; such accounts are then rooted and validated in the direct experiences of everyday life. The main concepts that formed the backbone of this study were indigenous knowledge (IK) and western knowledge. The researcher has already defined and discussed these terms, with citations of the opinions of other researchers, in Section 2. A conceptual framework was adapted from Barnhardt and Kawagley (2005) and is shown in the next page in Figure 1.
Figure 1: Conceptual framework adapted from Barnhardt and Kawagley (2005).

In an attempt to design guidelines for an intervention, to assist science teachers with the integration of indigenous knowledge in teaching of scientific concepts, the conceptual framework was used to identify IK involved in biotechnology examples used for teaching cellular respiration. Western knowledge was then used to explain the scientific concepts involved in the biotechnology examples from IK. Overlapping of the two knowledge systems was done during the treatment given to experimental group only and during development of the cognitive test that was written by both the experimental and control groups. Development of the intervention material explaining how researcher integrated IK into western science to explain science inherent in biotechnology examples was explained in more detail later.

In an effort to assist learners to understand biotechnology concepts better when IK examples are used to explain the science inherent in the western knowledge by overlapping IK and western science, the researcher envisaged using instructional scaffolding in the teaching of biotechnology concepts.
Hence, the researcher expected that the intervention would help learners to improve their achievement scores when biotechnology concepts are examined. This is aligned to the work by Rohandi and Zain (2011). They suggest that when topics relevant to everyday life experiences are used to teach concepts in science, it makes understanding of those concepts easier.

Indigenous knowledge systems and western knowledge systems have methodological and epistemological differences, as shown in the framework of Barnhardt and Kawagley (2005) given in Figure 1 earlier in this section. However, if the two ways of knowing overlap, that is if indigenous knowledge is incorporated into western knowledge or the other way around, a common ground would be established. They propose that an overlapping framework brings together two ways of knowing (indigenous and western) that were at one time divergent, to form a holistic system that can better serve all learners at the same time, simultaneously preserving the integrity of each component of the overlapping systems.

When IK and western knowledge are overlapped to form a conceptual framework, it helps the learners to connect their cultural experience with what they learn in the science classroom (Moje, Collazo, Carrillo & Mark, 2001). This instruction helps mediate learners' navigation between different discourses, thereby helping them relate their cultural experiences to their experiences in science classrooms (Moje et al., 2001). The framework adopted for the current study helped to move the role of indigenous knowledge and learning from the margins of the educational system to its centre (Barnhardt & Kawagley, 2005). The researcher believes that overlapping the IK and western knowledge frameworks enhances the notion that biotechnology is a science with unequivocal social, political and ethical implications, as suggested by Dawson and Schibeci (2003).

The framework presents science knowledge in a way that local people would understand and value. A learner taught through a curriculum employing such a framework is envisaged to be more open minded, be able to make empirical observations in natural settings, verify results through repetition and make inferences and predictions (Barnhardt & Kawagley, 2005). Such a learner is expected to be motivated to learn if knowledge is explained initially through the indigenous way of understanding. Barnhardt and Kawagley (2005) proposed that once learners understand the importance of the knowledge being presented, then knowledge could be presented in western terms.

5 RESEARCH PROCEDURE

5.1. Document Analysis
At the start, an in-depth analysis of the Life Sciences NCS and CAPS documents was conducted, in order to find out what content was prescribed to be taught in the biotechnology topics and what specific indigenous biotechnology examples were mentioned in the documents. It should be noted that in South Africa biotechnology is not taught as a separate school subject but appears as a topic in the Life Sciences curriculum. Furthermore, Life Sciences examiners’ reports from 2009 to 2015 were analysed with a view to identifying examiners’ observations
and opinions on learners’ achievements, and topics shown to be problematic in the matriculation examinations. The primary reason for undertaking the document analysis was to guide the formulation of research questions and hypothesis.

5.2. Development of the teaching materials and lesson plans for intervention
In the second stage, the researcher identified examples of indigenous practices and beliefs that could be used to teach biotechnology concepts. Each example was systematically broken down into steps. In each step, the indigenous practice involved was highlighted, along with the western knowledge that explained the science behind the step. This was carried out in line with suggestions made by Bruner (1965) that content should be structured so that the learner can most easily grasp it. By breaking down content into parts, identifying indigenous beliefs and practices and using scientific knowledge to explain the parts, the researcher envisaged that content would become more accessible and easier for learners to learn.

5.3. Training of teachers
Grade 11 Life Sciences teachers who were teaching learners belonging to the experimental group were invited to attend a training workshop on how to integrate indigenous knowledge examples into the teaching of biotechnology concepts. After the training, the teachers were asked to prepare and present a lesson plan and deliver a lesson on including indigenous knowledge examples in teaching biotechnology concepts. This was done to validate whether the teachers had understood the training.

The training of the teachers who were to teach learners in the experimental group in the Gert Sibande district was carried out before the date scheduled in the annual teaching plan or pace setter when the topic of cellular respiration would be taught. Teachers of grade 11 Life Sciences in schools belonging to experimental group then implemented the intervention in their schools. Teachers who were involved in the study thus became research assistants. Those teachers in the experimental group were trained so that they all implemented the intervention in a similar fashion to enhance validity of the results. Those in the control group were asked to teach cellular respiration as they had normally done and then to give the post-test at the time specified by the researcher.

5.4. Intervention
In order to prepare an intervention for the research, the first step was a critical document analysis, related particularly to Curriculum Assessment Policy Statement, National Curriculum Statement and Life Sciences examiner’s report documents. The findings of this document analyses informed the development of intervention materials and a researcher-made cognitive test. The researcher acknowledges that the curriculum documents mentioned two examples of indigenous biotechnology products; specifically, traditional technologies to produce beer and bread. Other examples mentioned by the curriculum would not necessarily be familiar to most learners, such as the use of microorganisms to produce insulin and antibiotics, because these involve modern biotechnology or genetic engineering.
The researcher was able to identify further indigenous biotechnology examples that could be used to teach some concepts of biotechnology to South African learners. These examples included making traditional beer (umqombothi, mentioned by the Life Sciences curriculum National Curriculum Statement and Curriculum Assessment Policy Statement), sour drink (mahewu/mageu), sour milk (amasi/maas), sour porridge; bread (mentioned by the National Curriculum Statement and Curriculum Assessment Policy Statement) and compost.

After identifying examples of biotechnology that were common and which should be familiar to South African learners, the researcher systematically broke down each of these examples into steps. For each step in each example the researcher identified the indigenous cultures and beliefs involved. The researcher then explained each of the steps in the examples using scientific knowledge. Learners who were in the experimental group were taught using these examples. On the other hand, learners in the control group were taught without the extra material on indigenous knowledge (examples with indigenous knowledge integrated into the examples). After the intervention had been implemented in the experimental group, both groups (experimental and control) wrote a researcher-developed achievement test.

5.5. Observation of teachers as they taught biotechnology concepts
Teachers from the experimental group were visited at their schools and observed in class to ensure that they implemented the intervention as agreed at the training workshop. The researcher also observed teachers in the control group while they taught cellular respiration. This observation was to ensure that they did not use materials developed for the experimental groups for teaching the topics of cellular respiration. It is possible that teachers in the control groups could mention indigenous examples, but the teachers were not expected to have treated the examples in the same systematic way that the researcher had done, as for experimental group.

6. RESEARCH METHODOLOGY

A positivist paradigm was adopted for this research. A positivist paradigm governed the formulation of research question, research purpose and collection of quantitative data. Quantitative research design was used to answer the main research question that read: How do the scores of learners taught biotechnology concepts using indigenous knowledge examples differ from those taught without using indigenous examples? As a quantitative research design, a quasi-experimental non-equivalent post-test control and experimental group design were used.

6.1 Sampling
Convenience sampling was used for choosing schools that participated in the study. Cohen et al. (2011) point out that when a population is widely dispersed, it would be completely impractical to spend time and money travelling around to test them. Nevertheless four different circuits were involved in the study in order to have increased representation of the population in the Gert Sibande
district. However, the researcher chose the sample from those to whom she had easy access, and the sampled schools were all within her 100km geographical radius. These schools included 404 grade 11 learners (in intact classes) and 7 teachers in the Gert Sibande district of Mpumalanga province of South Africa. Purposive sampling was used to choose the teachers who participated in the study. In this type of sampling, the researcher hand-picked the cases to be included on the basis of possession of the particular characteristics being sought (Cohen et al., 2011). The teachers who participated in the study were those who teach grade 11 Life Sciences in the sampled school.

6.2 Research instrument
The researcher used a researcher developed post-test as the main data-collecting instrument for securing quantitative data. Results to determine the effect of the treatment are gathered at the end. The results obtained from experimental group were compared with those of the control group. T-test was used to determine if the treatment had a significant effect (Cohen et al., 2011).

6.3 Ethics
Permission to conduct research studies in the sampled schools in the Gert Sibande district of Mpumalanga province of South Africa was sought from the head of department of the Mpumalanga Department of Basic Education, Regional Director of Gert Sibande district, curriculum implementer of Life Sciences, the circuit managers, principals, grade 11 Life sciences teachers and grade 11 learners in the sampled schools. Clearance from the UNISA Research Ethics Review Committee was sought.

FINDINGS

Results
The main research question that guided the collection of quantitative data was: How do the scores of learners taught biotechnology concepts using indigenous knowledge examples compared with those taught without using indigenous examples?

Results of the post-test were collected and independent t-tests conducted for all questions resulted in the rejection of the null hypothesis of equal means as all p-values were less than 0.05. These results indicated that the mean scores of experimental and control groups were not equal (experimental group m=13.69 and control group m= 7.72). Although both groups did not achieve high scores, a t-test indicated that experimental groups achieved higher scores compared to control groups t value of 10.018 was obtained at p value of 0.000. Since the p value was less than 0.05, null hypothesis for equal means was rejected. The effect size was calculated and a large effect size was obtained η²=0.199.

Generally, the performance of learners was poor, however learners taught using biotechnology examples were able to give examples of biotechnology products (cheese 41%, yoghurt 30%, umqombothi 49% and sour milk 25%) compared to the control group (only 2% stated cheese and 2%
stated alcohol). Post hoc analysis for question 7 which required learners to define terms and give examples of biotechnology revealed three subsets. A2 high school which was significantly similar to A3 high school (Sig=0.230 i.e. p>0.05 m=2.33) and B2 combined school (Sig=0.302 i.e. p>0.05 m=2.61) out competed the other learners with a mean score of m=3.27. Second subsets comprised B3 high school (m=0.68) which was statistically similar to B1 combined school (Sig=1 i.e. p>0.05 m=0.71). The third subset comprised A1 (m=1.45) which was statistically similar to A3 high school (Sig=0.230 i.e. p>0.05 m=0.2.33) and B2 combined school (Sig=0.302 i.e. p>0.05 m=2.61). Schools in the A group were experimental groups while schools in the B group were control groups.

Questions that required learners to give explanations of various steps in biotechnology processes were poorly answered by the learners. This showed that learners in general do not understand the function of yeast. Yeasts are very small unicellular organisms invisible to the naked eye. What is learnt in the classroom about how yeast functions is abstract and learners failed to understand functions at sub-microscopic levels.

Learners failed to explain the function of the wheat flour as a source of enzymes to ferment the drink, leftover pap as the source of carbohydrate and placing the suspension on the window sill for higher temperature to speed up the fermentation process. Learners simply fail to explain how higher temperatures increase the catabolic functions of yeast. Such answers concretise propositions made by the researcher that learners fail to offer explanations when required to.

7.2 Discussion of results

Findings of this study have shown that learners taught using biotechnology examples were able to give examples of biotechnology products (cheese 41%, yoghurt 30%, umqombothi 49% and sour milk 25%) compared to the control group (only 2% stated cheese and 2% stated alcohol). Post hoc analysis revealed that two of the three experimental groups obtained significantly higher marks than the other schools. These results are slight improvements to results obtained by Atagana (2009) who found out in his study that only 35% of the study subjects could give examples of biotechnology.

Findings of this study have also shown that experimental group performed better than the control group. The effect size was calculated and with η2 =0.199 a large size effect was obtained. The researcher therefore confidently concluded that experimental groups performed better than control groups. This result has a number of implications. This implied that when indigenous examples are used to teach biotechnology topics, learners obtain better marks in the test. This is cause for celebration. Secondly conceptual framework developed for this study could be adapted by teachers to assist them to overlap indigenous knowledge with western knowledge in order to teach a kind of science that is relevant to everyday life experiences of the learners so as to make understanding of those concepts easier (Rohandi & Zain, 2011).

The researcher investigated effects of integration of indigenous knowledge in the teaching of secondary school learners. The results of the study have made a contribution to the research field.
since it is said that more published research on IK in South Africa has focused on adult populations (Vhurumuku & Mokeleche, 2009 XE "Vhurumuku E. & Mokeleche M., 2009"). Moreover, the research paper was peer reviewed and published in conference proceedings. It has contributed to knowledge in both education and indigenous knowledge. It has further suggested areas for future exploration. The author provided findings for study conducted at a different context than the study conducted in South Africa focused on the grade 11 life science learners in Gauteng and Kwazulu Natal provinces (Atagana, 2009). While the researcher focused on grade 11 life sciences learners, it targeted learners in the Gert Sibande District of Mpumalanga province. Its aims were not only to find out knowledge levels on biotechnology. In this study, the researcher extrapolated the study conducted in South Africa by further suggesting ways of teaching that integrated IK with western knowledge thereby assisting to improve the scores of learners when biotechnology concepts are tested.

8. CONCLUSION

While inclusion of indigenous knowledge in the teaching of biotechnology concepts resulted in the improvement of scores, the researcher found out that learners in both groups failed to convincingly explain the science involved in bread making or the functions of microorganisms in biotechnology concepts. These indicated that the topics of microorganisms are probably too abstract for grade 11 rural learners to comprehend. Consequently, there is a need to develop teaching methodologies that could assist learners in understanding such abstract concepts in Life Sciences.

Teachers play an important role in guiding learners in the learning process and there is a need to train teachers in order to equip them with the necessary indigenous knowledge, skills, and values required to guide their learners and facilitate effective learning in the classroom. When knowledge is presented in a way that is familiar to learners, the learners improve their scores on biotechnology concepts and become citizens who can make informed decisions.

Secondly, the findings of this study could be useful to the pre-service and in-service teacher training instructors that would also need to adjust their instructional methods to integrate indigenous knowledge in the courses for training teachers. Since a conceptual framework was developed it could be used by teachers for integration of indigenous knowledge in teaching of science concepts.

Intervention seemed to assist learners in learning specific indigenous examples better resulting in improved overall scores; however, learners seemed to lack the skill to explain in western terms or science inherent in the examples. More research is invited to find ways of teaching abstract concepts such as the role of yeast, bacteria, and fungi in biotechnological processes in such a way that learners not only relate to them but can also be exposed to visual images that can best assist in acquiring abstract concepts. For example, the use of computer-generated programmes which can help learners view microscopic organisms during biotechnological processes at sub-microscopic levels with indigenous knowledge integrated into it, in order to enable learners to identify with the knowledge they are gaining.
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TOWNSHIP TEACHERS’ VIEWS ON THE INTEGRATION OF AFRICAN INDIGENOUS KNOWLEDGE IN NATURAL SCIENCES TEACHING

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Abstract
The study aims to explore township teachers’ views on the integration of African Indigenous Knowledge (AIK) in Natural Sciences (NS) teaching. The study uses an explanatory sequential mixed method research design. A validated instrument, Views on the Nature of Indigenous Knowledge (VNOIK) questionnaire, will be administered to 80 NS teachers in Gauteng township schools. Based on the findings from the analysis of data from the questionnaires, six teachers will be purposively selected, two showing an informed view, two showing a partially informed view and two showing an uninformed view. These teachers will be interviewed to determine how their views inform their practice. The findings will contribute towards building a knowledge base upon which the development, design and implementation of science teacher professional development programs can be built.

Keywords: African indigenous knowledge, teachers’ views, integration, Natural Sciences

Introduction
Science teachers, worldwide and locally, are failing to keep up with the current paradigm shift towards promoting science education that is relevant to learners’ everyday life. By incorporating learners’ rich cultural background, which includes their everyday experiences, beliefs and cultural practices in science teaching, teachers tap into the strengths the learners bring to the science classroom (Mavuru & Ramnarain, 2014). Integration of AIK in science teaching and learning contributes towards learner understanding of difficult science concepts and the subject matter as a whole (Pretorius, de Beer & Lautenbach, 2014). Most township teachers acknowledge the need to incorporate AIK into science teaching (Msimanga & Shizha, 2014), as prescribed by the Curriculum and Assessment Policy Statement (CAPS) document (Department of Basic Education, 2011). They however lack the know-how to integrate AIK (Cronje, de Beer & Ankiewicz, 2014). This means that NS teaching is not aligned to the CAPS document, which alludes to the importance of valuing indigenous knowledge. Accordingly, Cronje et al (2014) argue for the need for South African teachers to incorporate AIK into their teaching.

The aim of this study is to explore the views of NS senior phase teachers on the nature of AIK and their practices when integrating it into their teaching. The study seeks to answer the research
questions: How do NS senior phase teachers view the nature of AIK? and How do their views influence their teaching practices?

**Methodology**

The study uses an explanatory sequential mixed method research design (Creswell, 2003). Both quantitative and qualitative data will be collected sequentially, and then merged to better understand the teachers’ views on the integration of AIK and their practices when integrating it in NS teaching.

Data collection will involve two phases: the first phase involves administration of an open-ended questionnaire: The Views of the Nature of Indigenous Knowledge (VNOIK) instrument (Cronje, de Beer & Ankiewicz, 2015) to 80 Grade 7, 8 and 9 NS teachers to determine their views about the Nature of Indigenous Knowledge (NOIK). The teachers will be conveniently selected from township schools within a range of 10km radius in Johannesburg Central District. The VNOIK instrument is suitable for the study as it was developed using examples local to the South African context.

In the second phase six teachers will be interviewed once in order to establish the relationship between their views and their teaching practices. An open-ended semi-structured interview schedule will be used to reduce concerns about researchers imposing a specific issue on participants (Abd-El-Khalick et al., 1998). The six teachers will be purposively selected based on their responses after analysis of data from questionnaires. Selection criteria will be two teachers whose responses to the VNOIK instrument show an informed view, two teachers showing a partially informed view and two teachers showing an uninformed view.

Data from the questionnaire will be analysed and quantified using a rubric designed by Cronje et al., (2015), which rates an informed view with a score of 2, a partially informed view with a score of 1 and an uninformed view with a score of 0. Interview data will be recorded (with teachers’ permission), transcribed verbatim and then analysed using Saldana (2009) manual coding method.

The findings are relevant to curriculum developers as they develop learning materials that incorporate relevant AIK content. Documenting teachers’ views about the integration of AIK may lead to the development of AIK instructional strategies in the science classroom. The findings will therefore contribute towards building a knowledge base upon which the development, design and implementation of teacher professional development programs can be built.

**References**


Abstract
Students experience natural phenomena in their everyday lives, which could either enable or constrain their understanding of science concepts. The purpose of this study was to explore in-service science teachers’ cultural beliefs about lightning and its uses as prior everyday knowledge in mediating learning of static electricity and its associated concepts. It comprised of 16 BEd(hons) in-service science teachers from Namibia studying through a certain university in the Eastern Cape, South Africa. Underpinned by an interpretive paradigm and informed by Vygotsky’s socio-cultural theory, a qualitative case study approach was adopted. Additionally, Ogunniyi’s Contiguity Argumentative Theory (CAT) was used as an analytical framework. Data were generated through whole class discussions, documentary evidence in the form of newsprints and worksheets, observations as well as students’ reflective journals. Data were subsequently analysed inductively to answer the research questions. From the analysed data, it emerged that the in-service science teachers had varied cultural knowledge on lightning. From the hands-on activities using easily accessible resources, they were afforded an opportunity to make sense of science concepts associated with electrostatics, but some students held on to their cultural beliefs about lightning.

Key words: In-service science teachers, scientific knowledge, local or indigenous knowledge, cultural beliefs, socio-cultural theory, CAT.

Introduction
Scholars who are proponents of indigenous knowledge (IK) believe that its inclusion in science classrooms can help facilitate border crossing (Aikenhead & Jegede, 1999). Le Grange (2007), for instance, cautions that neglect of IK might result in conflict between students’ existing knowledge and the science taught at school. To Kibirige and van Rooyen (2006) and Shiza (2013), such cultural knowledge represents wisdom developed over years and has been passed on from generation to generation.

Inspired by these debates, scholars such as Mavuru and Ramnarain (2017), Mhakure and Otulaja (2017), Mukwambo, Ngcoza and Chikunda (2014) and many others, propose that the socio-cultural contexts of students should be taken seriously in science classrooms. This suggests that there is a need to contextualise and make science accessible and relevant to the students’ everyday lives. It is
against this caveat that in this study we explored in-service science teachers’ cultural beliefs about lightning with a view to mediate learning of electrostatics. The study was thus guided by the following research questions:

- What are BEd (hons) in-service science teachers’ cultural beliefs about lightning? And how are such cultural beliefs about related to or not to scientific concepts?
- How do hands-on practical activities using easily accessible resources enable BEd (hons) in-service science teachers to make sense of electrostatic concepts?

**Theoretical Framework**

This study is underpinned by Vygotsky’s (1978) socio-cultural theory as a theoretical framework. Central to socio-cultural theory is the notion that learning entails moving from a social context to an individual understanding. That is, social interaction taking place in socio-cultural contexts (Mavuru & Ramnarain, 2017) are pivotal during the teaching and learning repertoires. Additionally, to complement the socio-cultural theory, Ogunniyi’s (2007a) Contiguity Argumentative Theory (CAT) was used as an analytical framework. CAT deals with the nature of interactions between distinctly different thought systems, in the context of this study, for example, scientific and non-scientific cultural beliefs about lightning. Concurring, Govender (2014) posits that central to CAT are possible explanations of how conflicts arise from two thought systems.

Ogunniyi further elaborates that CAT has five cognitive states, namely, dominant, suppressed, assimilated, emergent and equipollent. A dominant state arises when one thought system is dominating, and hence resulting in other thought systems being suppressed or assimilated. An emergent state on the other hand is characterized by evolvement of knowledge in circumstances where there was no prior knowledge. Finally, an equipollent state is experienced when two competing thought systems are equally powerful. It should be recognized, however, that these cognitive states are in a dynamic state of flux (Ogunniyi, 2007a).

**Methodology**

This study is underpinned by an interpretive paradigm. Within the interpretive paradigm, a qualitative case study was employed (Cohen, Manion & Morrison, 2011; Bertram & Christiansen, 2015). It comprised of 16 BEd (hons) Science Elective students from Namibia studying with a certain university in South Africa in the Eastern Cape. All those students freely gave informed consent to take part in this study. Data were generated through whole class discussions, documentary evidence in the form of newsprints and worksheets, observations as well as reflective journals.

The students were divided into four groups of four and were subsequently tasked to discuss and write their cultural beliefs about lightning on newsprints. Thereafter, they had to analyse and classify the cultural beliefs into whether they were scientific, non-scientific or not sure. Each group had to make a presentation to the entire class on their findings and this was followed with some discussions and
arguments. Finally, students were engaged in hands-on practical activities using easily accessible resources and they had to document key scientific key concepts on worksheets. Thereafter, they had to do mind-maps followed with concept maps. Data were subsequently analysed inductively to answer the research questions.

Findings and Discussions

It emerged from the findings that some of the in-service science teachers’ cultural beliefs about lightning were concerned with protective measures from this natural phenomenon (Webb, 2013). For example, the participants mentioned that people should cover shiny objects such as mirrors, should not wear metal objects and should not come into contact with electronic devices such as radios and cell phones. Also, they highlighted that people should not stand under trees when there is lightning because tall trees were prone to being struck by lightning. These reflect the dominant scientific views held by these students as espoused by Ogunniyi (2007a). Other participants mentioned that lightning was sent by sangomas (Webb, 2013) and that generated many discussions. As highlighted by Le Grange (2007), these discussions caused some dissonance or uncertainty amongst some students.

From the hands-on practical activities, the in-service science teachers were able to come up with scientific concepts on electrostatics, which they subsequently used to make mind-maps and concept maps. However, some students could not completely do the border crossing but were able to hold both views (equipollent) together (Govender, 2014; Ogunniyi, 2007a).

Conclusion Remarks and Recommendations

It emerged from the findings of this study that exploration of the cultural beliefs about lightning created an enabling constructivist learning environment which promoted discussions and arguments amongst the participants. The participants also embraced their diverse socio-cultural backgrounds, cultural knowledge and cultural revitalization (Mavuru & Ramnarain, 2017). Pertaining to the analysis, classification and discussions of the cultural beliefs about lightning as well as from the reflections, Ogunniyi’s (2007a) CAT states, namely, dominant, assimilated, suppressed, emergent and equipollent were illuminated from the data although some were not explicit. On a final note, the study recommends that there is a need for science teachers to integrate local or indigenous knowledge in their science classrooms. As evidenced in this study, this could have many benefits in terms of making science relevant to the learners’ everyday lives.

References


THE EFFECT OF USING AN INDIGENOUS TECHNOLOGY, THE PRODUCTION OF OSHIKUNDU, AS THE BASIS FOR A PRACTICAL INVESTIGATION

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Abstract
This study sought to explore how indigenous knowledge and practices through a practical activity of making oshikundu, enabled or constrained learner-engagement and sense making of the concept of rates of reactions in Namibian schools. Underpinned by an interpretive paradigm, the study tried to describe and understand how learners make sense of their world, using a case study approach. The study is informed by Vygotsky’s socio-cultural theory, which recognises that learning and meaning-making originate from social interactions among individuals. Observations were used to explore how learners made sense of rates of reactions during lessons. In addition to observations, three learners were interviewed to gather data on how the practical activity of making oshikundu enabled or constrained Grade 11 Physical Science learners in (a) learner engagement and (b) sense making of the concept of rates of reactions. The study thus recommends that, where appropriate, indigenous knowledge and practices be integrated into Physical Science classrooms for effective teaching and learning and sense making of science.

Keywords: Socio-cultural theory; indigenous knowledge; prior everyday knowledge; learner engagement; sense making

Introduction

The Namibian Examiners’ Reports (MoE, 2013-2017) consistently point to the fact that learners are not doing enough practical activity in their science lessons. However, in Chemistry, in particular, there is much scope to motivate learners to engage with the topic, by using more examples from their everyday life - in their community and indigenous processes and knowledge (Namibia. NSSCO, 2010). It is against this background that, in this paper, the role and importance of taking into consideration indigenous ways of knowing or practices during teaching and learning repertoires in science classrooms was researched. Apart from the benefits, the challenges associated with using indigenous knowledge in science teaching and learning will also be highlighted. The study was thus guided by the following research question:

- How does a practical activity on making oshikundu enable or constrain learner engagement?
- How do practical activities using oshikundu enable or constrain sense making of concepts on rates of reactions by learners?
Background and aim of the study

Kasanda, Lubben, Gaoseb, Kandjeo-Marenga, Kapenda and Campbell (2005) argue that learners learn more effectively when they already know something about a content area and when concepts in that area mean something to them and to their particular background or culture. It is against this backdrop that the aim of this study was to enable sense making of concepts on rates of reactions through the indigenous practice of making oshikundu, a beverage made in most homes in Namibia. Oshikundu is a homemade traditional drink containing a lot of energy and very low percentage of alcohol.

IK has similarities with desirable classroom practices (Ogunniyi & Ogawa, 2008). For example, it is relevant, leading to active participation and it is essential in supplementing western science (ibid). In the same vein, Mhakure and Otulaja (2017) contend that indigenous knowledge systems (IKS) be integrated with western science knowledge (WSK) in order to empower learners in various cultural contexts.

Despite the positive aspects associated with the inclusion of indigenous knowledge, Mukwambo, Ngoza and Chikunda (2014) state that IK is implicit in nature and is usually accompanied by myths. These factors may discourage the inclusion of IK in the science curriculum.

Theoretical Framework

Vygotsky’s (1978) socio-cultural theory has contributed significantly towards science and science education. Vygotsky argues that construction of knowledge depends on the interdependence of social and individual processes (John-Steiner & Mahn, 1996; McRobbie & Tobin, 1997). “Human activities that take place in cultural contexts, are mediated by language and other symbol systems, and can be best understood when investigated in their historical development” (John-Steiner & Mahn, 1996, p. 191). According to socio-cultural theory, meaningful learning occurs when there is social interaction between learners and those with more life experience.

Research Design and methodology

An interpretive paradigm was used with a socio-cultural theory, to study how Physical Science learners make sense of rates of chemical reactions during lessons, using an indigenous practical activity of making oshikundu. This paradigm allowed us to understand the situation and to interpret meaning within the social and cultural context (Mavuru & Ramnarain, 2017) of the natural setting of this research study, particularly, ‘rates of reactions’ in Physical Science. The paradigm employed a qualitative case study which allowed in-depth exploration of learners trying to make sense of the concept of rates of reactions through the inclusion of the indigenous practice of making oshikundu.

Research Site and participants
The research study involved Grade 11 learners because ‘rates of reactions’ is covered in year one of the NSSCO Physical Science syllabus. One Grade 11 class of 22 learners was chosen for this study. All 22 learners participated during lesson observation of the practical activity of making oshikundu.

**Data Gathering Techniques**

The main data gathering techniques used in this study was observations and interviews.

*Observations*

The researcher observed learners during a practical activity using a classroom observation schedule pertain to aspects of learner engagement and sense making. Observation of the practical activity helped the researcher to understand whether engaging learners in practical activities, enabled learners to make sense of scientific processes in relation to rates of reactions.

*Interviews*

In a semi-structured interview, the researcher uses an interview schedule, which is a set of questions in a predetermined order. In this study, semi-structured interviews, using 14 open-ended questions, were conducted individually with three (average, above average and below average) learners to find out how the practical activity (making oshikundu) enabled or constrained their engagement and their making sense of the concept of rates of reactions.

**Findings and Discussions**

This practical activity of making oshikundu, shows how one can link it to the rate of a reaction, where the speed at which reactants are converted into products depends on the temperature, addition of a catalyst and concentration. We therefore concur with Woodley’s (2009) study that suggests that teachers involve learners more in designing and carrying out practical experiments and observations. The study maintains that good practical activities help learners understand and make sense of science concepts – for example, if you were looking at how much carbon dioxide is produced when magnesium carbonate and hydrochloric acid react, you would vary the concentration of the acid, surface area, temperature and presence of a catalyst, for an in-depth understanding.

**Conclusion and Recommendations**

The main findings of this study concluded that the integration of indigenous knowledge with school science promotes more learner engagement and sense making in the subject. The study found that the inclusion of the indigenous knowledge practice of making oshikundu in a Physical Science lesson on rates of reaction enables the learners to make sense of the concept. Moreover, sense making can be made easier through the use of practical activities during instruction. The learners’ level of participation, motivation, interest and enjoyment also increases because they have the ability to connect their everyday experiences to classroom science.

Based on the findings of this study, we recommend that relevant indigenous knowledge and practices should be incorporated into Physical Science lessons.
References


Pedagogical Reasoning refers to the thinking that guides teachers as they transform content knowledge in ways that are both pedagogically powerful and understandable to a variety of students (Pella, 2015). Research shows that pedagogical reasoning that is informed by Topic Specific Pedagogical Content Knowledge (TSPCK) can result in the effective transformation of content knowledge (Zimmerman, 2015). My aim in this study was therefore to investigate the extent to which pre-service teachers, who specialise in the Life Sciences, were using the TSPCK framework to guide their planning of lessons and their teaching, after having gone through TSPCK interventions in their teacher education courses. The questions that guided this study were:

1. What informs Life Science pre-service teachers’ pedagogical reasoning during the planning and teaching of specific lesson topics?
   a. How do Life Science pre-service teachers plan their teaching?
   b. How do Life Science pre-service teachers enact their lessons?

Literature Review

According to Wilson and Peterson (2006), teachers need not only develop a knowledge base for teaching, but also be able to make reasoned decisions regarding their teaching. Pedagogical reasoning reflects a teacher’s thinking about learning and teaching and this thinking is observable in practice. Shulman’s model of pedagogical reasoning suggests that in order for good teaching to happen, a teacher must go through a cycle of pedagogical activities including; comprehension of subject knowledge, transformation of subject knowledge into teachable representations, instruction, evaluation of students’ learning and teacher’s performance, reflection and new comprehensions (Starkey, 2010). Pedagogical reasoning and action can therefore be said to be a set of processes that are important to the development of a teacher’s pedagogical content knowledge (PCK) where by engaging in pedagogical reasoning and action, teachers shift from their initial understandings of content knowledge to developing PCK.

PCK has the potential to impact quality teaching but continues to be tacit in nature (Kind, 2009). In response to this, many researchers since Shulman proposed models of PCK that attempted to unpack
its complex nature and make it observable. One such model is one developed by Mavhunga and Rollnick (2013). The Topic Specific PCK model is presented as a separate entity that stems from subject matter knowledge and is transformed in a specific way for a specific topic (Zimmerman, 2015). Here, transforming SMK into topic specific PCK requires the teacher to possess (1) knowledge of the learner’s prior knowledge including misconceptions (2) an awareness of curricular saliency, (3) a clear idea of what is easy or difficult to teach, (4) knowledge of the representations and analogies that are needed to aid in the conveying of concepts and (5) the conceptual teaching strategies that will be most effective for teaching that specific topic. As such, this study was imbedded in the notion that the value of PCK lay in its topic specific nature, particularly the capacity to apply pedagogical reasoning in the transformation of concepts within a topic. In this way, pre-service teachers planned and enacted TSPCK would be observable and measurable. The TSPCK model and its links to PCK thus made up my theoretical framework.

**Research Methodology**

This study design involved use of both quantitative and qualitative approaches but it was not mixed methods research design.

Qualitative research design begins with conscious questions and assumptions that serve as the foundation for the study (Guba and Lincoln, 1994). This study assumed that 4th year PSTs would be using the TSPCK framework to inform their pedagogical reasoning during planning and teaching of their lessons but what we did not know was the ways in which or the extent to which they would make use of the framework for content knowledge transformation purposes. The value of qualitative research design in this study was in its ability to provide detailed descriptions of the phenomena central to this study in a way that is subjective, interpretive and process orientated.

As its own entity, quantitative research design is used to quantify a problem by generating numerical data or data that can be transformed into usable statistics (Muijs, 2011). For example in this study, I take the position that a minimum of three components of TSPCK must appear in each lesson in order to able to say that the framework is indeed being used for the transformation of content knowledge. This approach therefore assumes that there is a fixed measurability of the data in question (Muijs, 2011).

Guba and Lincoln, 1994 advocate for the integration of qualitative and quantitative methods as neither one is better than the other rather, the two enhance each other as they highlight different aspects of the data. In this way, the multi-method approach can produce a more comprehensive vision of the phenomena (Guba and Lincoln, 2004). The value of this approach in this study was that it allowed me to yield data in different forms and derive knowledge, from this data, from different standpoints. This it was hoped, would increase the validity of my findings.

**Research Participants**
The participants were three 4th year PSTs who were registered for the B. Ed program in the FET phase and doing Life science as a major subject in 2018. These PSTs did a secondary methodology Life Science course in their 3rd and 4th year of study which is guided by the TSPCK framework. In this course, the PSTs are taught how to use the framework to effectively transform the Life Sciences content into a form that is understandable and suited to a variety of learners’ needs. In order to pick my final research participants, I looked at where the PSTs who had volunteered to participate in the study were placed for teaching experience. The three PSTs who were chosen as participants were chosen according to the high schools, they had been placed for teaching experience practicals. These high schools are relatively close to each other and therefore easy to access from one to the other which allows for a uninterrupted data collection as I would be able to move from one school to another for lesson observations and recording. These high schools were also work according to a CAPS pacesetter meaning they would be teaching pretty much the same topics on a weekly basis. The three PSTs were also chosen as they would be teaching Life Science to either grade 10 or 11 during the Teaching Experience period in July and August 2018.

**Data Sources and Collection**

There were three data sources in this study;

1. Lesson plan documents: to see how the PSTs plan to enact their lessons. It was anticipated that implicitly the lesson plans will reveal PSTs’ pedagogical reasoning in terms of how they plan to teach the content knowledge and will bring out aspects of TSPCK that may have been used.
2. Video and audio taped lesson observations: the video recordings were for finding out evidence (if any) of manifestation of planned TSPCK during lessons.
3. Post lesson video stimulated recall interview: the PSTs and the researcher will watch the video recordings of each observed lesson. PSTs will be asked to explicitly describe their pedagogical reasoning behind the teaching and learning activities that happened during the lessons. This, it is hoped, will provide evidence of whether or not the PSTs are using pedagogical reasoning that is guided by TSPCK in their planning and teaching.

Use of these three sets of data will allow me to capture different dimensions of the same phenomenon. This is necessary considering that PCK and pedagogical reasoning are elusive in nature. This further allows for the triangulation for the data as enhances the validity and reliability of the study.

**The way forward...**

Collection of lesson plans has been completed and analysis is underway. The researcher is in the process of collecting data from sources 2 and 3. It is hoped that this research will be complete by December 2018 and that a short paper with results will be ready by the time of the conference.
References


Zimmerman, G. (2015). The design and validation of an instrument to measure the Topic Specific Pedagogical Content Knowledge of physical sciences teachers in electric circuits.
DIGITAL INEQUALITIES AND SELF-EFFICACY IN AN AUGMENTED PROGRAMME
FLIPPED CLASSROOM
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Keywords: Physics; Self-efficacy; Digital Inequalities; Flipped Classroom; Extended Programme; Augmented Programme

Introduction

The inclusion of online resources in course design at tertiary education institutions has been growing in popularity over the last few years and can take a variety of forms, one of which is the flipped-classroom. A flipped-classroom approach introduces course content online prior to face-to-face contact sessions dedicated towards higher-order tasks such as problem-solving, debates, and discussions with instructor intervention and feedback being immediately available to assist students in these tasks (Bishop & Verlegar, 2013; Gilboy et al., 2015). This approach has been shown to increase self-efficacy in a general student population (Thai et al., 2017). It is expected that this approach will require some familiarity with online instruction and internet access to be effective, which is a potential challenge in its implementation at South African universities as a substantial portion of the country’s population does not have internet access and those that do largely connect to the internet via a mobile device (such as a cell phone) when not on campus grounds. These significant digital inequalities: differences in access to the internet and associated technology, in skills associated with internet usage, and in levels of usage and familiarity (Ovedemi, 2012) need to be investigated and addressed so as not to undermine the viability of the flipped-classroom approach. The participants involved in this study are all at-risk students in the sense that they have enrolled in an augmented extended 5-year engineering degree, which is an alternative entrance to a 4-year engineering degree for those who do not meet the minimum requirements. The augmented degree students receive temporary intervention measures during their first two years at university to succeed academically.

Self-efficacy refers to the confidence an individual has in their ability to execute tasks necessary for success (Bandura, 1982). Students with high self-efficacy tend to be more invested in performing the required tasks and will dedicate resources towards academic goals (Beck & Schmidt, 2012). Higher levels of self-efficacy have been linked to higher student success in at-risk students (Vogel & Human-Vogel, 2015). Improving self-efficacy in at-risk students is thus essential to avoid relapse once any temporary intervention is removed.
Methodology

Research Questions:
1) Does flipped-classroom increase self-efficacy in the at-risk students enrolled in the augmented programme?
2) Do digital inequalities present at South African universities hinder the implementation and efficacy of the flipped-classroom and influence the self-efficacy of students?
3) What are students’ reflections on flipped-classroom in an augmented programme?

Research Strategy:

The study will be implemented in a first-year undergraduate additional physics course, which acts as a conceptual bridge for a traditional physics module. All participants take the additional physics module at the same time as the traditional module which operates under contact only instruction. The first lecture will be dedicated to a course introduction and pre-tests for self-efficacy and digital access/competency. Flipped classroom will then be implemented with online lectures once per theme followed by 2-4 contact sessions per theme focused on solving problems in a social constructivist setting. Active learning is encouraged using Clickers and the immediate provision of feedback during the session. The course runs over a 12-week period covering 8 themes. Post-tests on self-efficacy as well as a final reflective survey will be done after the completion of the course prior to their final exam in the traditional module.

Focus groups will be conducted after the final exam in the traditional module centred on student perceptions on the flipped-classroom approach of the additional module in comparison to the approach of the traditional module.

The Way Forward

At the time of submission, tests for self-efficacy within a physics (or similar) course still need to be sourced and adapted. A potential tool has for measuring physics developed by Çalışkan (2007) but still needs to be investigated for suitability. All surveys will be issued as paper surveys and then digitally captured afterwards to ensure that digital inequalities do not present an issue to the study.

References


Abstract:
The focus of the study was to determine the nature of worldview predispositions held by pre-service teachers in four non-western countries namely, Botswana, Brazil, Egypt and Japan. Data were collected from a purposive sample of consisting of 185 subjects using a questionnaire. Snapshots of the preliminary findings indicate that the subjects, regardless of their cultural differences, hold multiple worldview presuppositions about diverse phenomena. However, it is not clear at this explorative stage the possible impact of such worldview presuppositions on their instructional practice or their learners’ conceptions of the same phenomena. This is the central concern of the main study.

Keywords: Worldview presuppositions, pre-service teachers, Botswana, Brazil, Egypt, Japan

Introduction

A subject that has been receiving increased attention among science educators worldwide, particularly among the neo-Piagetian and constructivist researchers, is the so-called worldview. According to Kearney (1984:1), a worldview is, “A culturally organized macrothought: those dynamically interrelated assumptions that influence much of people’s behaviour, how they make decisions and organize their symbolic creations and indeed their ethnophilsosophy in general.” In other words, people’s worldviews control their beliefs, attitudes, predispositions, sense of identity, actions as well as the way they relate or react to situations around them. According to Cobern (1993) a worldview is a culturally dependent, generally subconscious, fundamental organization of the mind, which is manifested as a set of presuppositions that predispose one to feel, think, act and react in a certain predictable manner. In other words, one’s worldview has an organizing value for experience in that it shapes a person’s way of thinking, acting, communicating and/or doing things in general (1st Author, 2007a).

A plethora of studies has revealed that when a teacher despises the worldviews that his/her learners hold, they tend to become alienated from school science. As a way to obviate this problem the Department of Education (DOE) in South Africa (DOE, 2002) like others embarked on the indigenization of school science to make it more relevant to learners’ sociocultural contexts (e.g.
Aikenhead & Elliot, 2007; Gonzalez, Moll, & Amanti, 2000). There is a general awareness among science educators worldwide today that learners’ worldviews and dispositions to the study of school science are conditioned to a great extent by what their teachers hold to be true even though such views may not be historically, philosophically and sociologically valid (e.g. 1st Author, et al, 1995).

Theoretical Framework

The study is underpinned by Kearney’s (1984) worldview theory (KWT) and the Contiguity Argumentation Theory (CAT) (1st Author, 2007a). KWT contends that people’s beliefs control their perceptions, predispositions and behaviours in general. CAT on the other hand posits that people’s perceptions are the products of a dynamic process involving cognitive conflicts, accommodation, assimilation, integrative reconciliation and adaptation-all in an attempt to harmonize with the context in vogue.

Considering the dominant role that teachers in non-western societies play in their classrooms in contrast to the relatively passive role of their learners, it seems worthwhile to determine possible impact of the beliefs and worldviews held by the former on their learners during the teaching-learning process.

Purpose of the study

The purpose the study is to explore: (a) the worldviews presuppositions held pre-service teachers; (b) compare the patterns of worldview presuppositions within each country and across countries; and (c) determine the sources of the worldview predispositions.

Methodology

Sample: The original plan was to use a purposive sample of 50 subjects from Brazil, Egypt, Japan, Kenya, South Africa and Zimbabwe. However, due to red tapes on particularly on “ethical clearance” in certain cases only 50, 62, and 32 filled questionnaires from Brazil, Egypt and Japan respectively were analyzed for this paper. For the same reason a previous data set consisting of 31 filled questionnaires from Botswana was added to provide some glimpse into a possible South African situation.

A purposive sample is preferred because of the tremendous benefit of dealing with subjects who are at the immediate precincts of the research team members. According to Patton (1987), a purposive sample is strategic and can yield quick and crucial information about critical cases. He stresses further that there are no fixed rules for determining the size of a purposive sample as long as it is large enough to be credible, given the purpose of the study. Credibility here implies refers to internal validity i.e. there is a match between the constructed realities of the correspondents and that of the researcher (Guba & Lincoln, 1987).
**Instruments:** The questionnaire deals with diverse phenomena presented in form of ten fictitious stories to which the subjects expressed agreement, disagreement or no opinion as well as indicate the sources of their worldviews. However, due to space limitation, data regarding the sources of their worldviews and other comments are not included here. To attain high validity the questionnaire was subjected to a series of revisions and rated 1-5 by two sets of 12 independent experts (1 = poor or unclear item and 5 = Excellent item). The inter-rater coefficients on the questionnaire before it was administered to the subjects ranged between 0.93 and 0.99 using a modified Spearman-Rank Difference Formula. An interview schedule to be derived from the subjects’ responses to the questionnaire would be administered later to 10 subjects per country.

**Analysis of data**

By adopting Kearney’s logical structuralism (see Cobern, 1993), we identified certain universal epistemological categories of worldviews pre-suppositions such as: magical-force controlled from the world which produces supernatural effects; mystical—appeal to an unexplainable mystery; spiritism—appeal to the world of gods, spirits, devils, ancestors, etc.; parapsychology—human force that is not explainable by known scientific laws; rational—appeal to reason and common sense; metaphysical—appeal to the notion of being apart from the physical body; pseudoscience—seemingly scientific notions but containing erroneous conceptions; science—appeal to mechanism, reductionism, formism, objectivism, empiricism, and so on. For ease of reference, these categories were re-grouped into four main themes namely: magic and mysticism; metaphysics, and pseudoscience, spiritism, rationalism and science (Table 1). However, due to space limitation, only a snapshot of the quantitative data is presented here.

**Preliminary Findings**

<table>
<thead>
<tr>
<th>Worldviews</th>
<th>Country</th>
<th>Agree</th>
<th>Disagree</th>
<th>No opinion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magic and mysticism</td>
<td>Brazil</td>
<td>31</td>
<td>56</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Botswana</td>
<td>27</td>
<td>47</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Egypt</td>
<td>35</td>
<td>52</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>14</td>
<td>68</td>
<td>18</td>
</tr>
<tr>
<td>Mean %</td>
<td></td>
<td>27</td>
<td>56</td>
<td>18</td>
</tr>
<tr>
<td>Metaphysics, parapsychology and pseudo-science</td>
<td>Brazil</td>
<td>22</td>
<td>56</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Botswana</td>
<td>39</td>
<td>25</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Egypt</td>
<td>37</td>
<td>40</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>20</td>
<td>55</td>
<td>25</td>
</tr>
<tr>
<td>Mean %</td>
<td></td>
<td>30</td>
<td>32</td>
<td>27</td>
</tr>
<tr>
<td>Spiritism</td>
<td>Brazil</td>
<td>9</td>
<td>74</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Botswana</td>
<td>15</td>
<td>61</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Egypt</td>
<td>32</td>
<td>55</td>
<td>13</td>
</tr>
</tbody>
</table>
An examination of Table 1 shows that the subjects from Egypt expressed the highest agreement (35%) on magic and mysticism, followed by Brazil (31%), Botswana (27%) and Japan (14%) respectively. Relative to metaphysics, parapsychology and pseudoscience the descending order was: Botswana (39%); Egypt (37%); Brazil and Japan (32%). On spiritism, the order was Egypt (32%), Botswana (15%), Brazil (9%), and Japan (5%) and on rationalism and science the order was: Brazil, (45%); Japan (42%); Egypt (39%); and Botswana (34%). Overall mean percentages of the themes, in a descending order were: rationalism and science (40%); metaphysics, parapsychology and pseudoscience (30%); magic and mysticism (27%); and spiritism (15%). In terms of disagreement the descending order was: spiritism (68%); magic and mysticism; metaphysics, parapsychology and pseudoscience (32%); and lastly rationalism and science. The fact that the “No opinion” category is less than a third percent for each worldview category suggests that the subjects most probably made conscious response choices.

From the foregoing, it is obvious that the subject’s other worldviews besides science which might influence their instructional practices and consequently, what their learners hold to be valid. The implications of this scenario certainly warrant a fuller treatment in the main study.

References


1st Author (2007a).


Abstract

Current research in physics shows that undergraduate students have poor conceptual knowledge of waves and optics. This research seeks to assess preservice physics teachers’ conceptual knowledge of mechanical waves using both qualitative and quantitative approaches. Year one Semester two (Y1,2) preservice physics teachers in a university in East Africa were exposed to a multiple-choice question (MCQ) assessment tests, mechanical waves conceptual survey two (MWCS2). The quantitative analysis of pre-service physics teachers’ responses to the MCQ assessment was taken beyond the conventional responses of assessing the correct options given by the preservice teachers by considering how their responses to the multiple choice were distributed using concentration analysis. This analysis sought to discover how effective questions are in seeking preservice teachers’ conceptual knowledge and the possible patterns of the distribution of their options. Interpretive qualitative analysis of preservice teachers’ responses to the questions was determined. The findings and the distributions showed that preservice physics teachers’ conceptual understanding and knowledge of mechanical wave are poor. Implications for teaching and learning of mechanical waves amongst pre-service physics teachers in view of their future professional practice were identified.

Introduction and Literature Reviewed

Topics in mechanical waves are major concepts which are taught yearly among first-year undergraduate physics and science education students in the university. An understanding of mechanical waves is fundamental and it is important for making sense of physical optics, quantum mechanics, electromagnetic radiation and other courses to be taught in the subsequent semesters. It is, therefore, important to ensure that the preservice teachers have a good grasp of conceptual knowledge of mechanical waves as the teachers’ progress in their studies and career training. There has been much research on mechanical waves (Caleon & Subramaniam, 2010; Eshach, 2014; Hrepic, Zollman, & Rebello, 2010; Kennedy & de Bruyn, 2011; Zeng et al., 2014). The previous research efforts of Tongchai, Sharma, Johnston, Arayathanitkul, and Soankwan (2009); and Barniol and Zavala (2016) investigated the university students’ conceptual understanding of four main topics: propagation, superposition, reflection and standing waves using mechanical waves conceptual survey (MWCS). In the previous work of Tongchai et all (2009) among undergraduate
In the latest research work of Barniol and Zavala (2016) efforts were made to analyze undergraduate physics students’ main difficulties in a mechanical wave using MWCS and to elaborate on the main difficulties in terms of students’ inappropriate conceptions based on previous studies. The previous research discussed in the different literature discussed earlier were conducted using undergraduate engineering and physics major students in the university as the subjects, none of the studies considered preservice teachers as the subject. This specific research assessed the preservice physics teachers’ conceptual understanding of mechanical waves by taking a closer look at their performance using both qualitative and quantitative approaches. The quantitative analysis of pre-service physics teachers’ responses to the MWCS2 assesses the correct options given by the preservice teachers by considering how their responses to the multiple choice were distributed using concentration analysis. It further sought for how effective questions are in seeking preservice teachers’ conceptual knowledge and the possible patterns of the distribution of their options. Qualitative approach took a closer look at why the preservice teachers’ answer the questions the way they were answered, by considering what is the conceptual understanding the required by the MCQ and what the wrong conceptions are. Efforts were put in place to explain the possible reasons for students’ wrong conceptions or misconceptions by looking deeply into the required conceptual understanding from the textbooks and the literature before judgments were made.

**Methodology**

This research is a case study mixed method research using year one semester two preservice teachers of a private university in Kampala, Uganda. Thirty Physics education students which constitute 30% of the total science education (physics, chemistry, biology, and mathematics) students in the year were the subjects for this study. Mechanical waves, sound, and optics are major topics in the core courses which are the basic requirement for their studies and professional training. The data collected was collected using Mechanical Waves Conceptual Survey Two (MWCS2) which is an improved version of MWCS1, a standardized physics assessment test developed by PhysPort. MWCS1 was used in the previous studies of Barniol and Zavala (2016). The questions focused on major topics on reflection, propagation, superposition and standing wave. MWSC2 consists of twenty-two multiple choice questions each having five options (A-E), one correct answer (the key) and four wrong answers (the distractors). The distracters are alternative conceptions, wrong conceptions or misconceptions which are critically examined in each question, option by option alongside with the key by making reference to other literature to assess preservice teachers’ conceptual knowledge of mechanical wave. The preservice teachers were exposed to the topics in the mechanical wave as stated in the course content for a period of 12 weeks after which the test was administered to them. Twenty-seven students out of thirty students participated in the research.

**Research Findings**
Data analysis was done using both qualitative and quantitative approaches. The following are the summary of the major findings.

**Quantitative Analysis**

The research finding using scores and concentration factor obtained in MWCS2 showed that preservice teachers’ scores distribution pattern is LL, LM, LH, ML, MM, MH, HL, HM, and HH. For example, a question with a low score and medium level of concentration will have LM-Type and a question with a high score and low level of concentration will have HL-Type etc. LH or HH type of response described one-model in which students have low scores and most of them picked the same distracter (LH model) which is considered as a strong indication that the question triggers a common incorrect student model. Similarly, an HH model indicates that students have high scores and most of them chose the correct answer which is expected if the students have a good conceptual understanding. The two-model situation happens when many of the responses are concentrated on two choices. If one of the two is the correct answer, the response type is an MM; if both choices are incorrect, the response type will be an LM. The implication of this is that a significant number of students use one or two incorrect models depending on the structure of the questions.

**Qualitative Analysis**

The analysis of preservice teachers’ responses to each question was done using interpretive qualitative analysis by considering their responses option by option to determine what informed their responses, their misconceptions, and alternative conceptions. It was observed in each of the subtopics that the percentage of preservice teachers who got the correct answer is very low Most of them have alternative conceptions which are wrong conception or misconceptions. The following are the summary of qualitative analysis in propagation and superposition principle subtopics; Propagation (Question 1-8)- Preservice teachers cannot relate volume with amplitude and poor conceptual understanding of the relationship between frequency, wave speed and wavelength ($v = f \lambda$). Superposition Principle (Question 9-12) - A confused memory and understanding of the principle of superposition. Confused understanding of, and lack of proper interpretation of destructive and constructive interference or superposition of wave motion. This may be because the students are not familiar with practical applications related to concepts as projected in the diagrams.

**Conclusion**

The MWCS2 was designed to evaluate university students’ difficulties in the subtopics considered in this study. Previous work done using MWCS was on university physics and engineering students in the literature reviewed while this study was basically on assessing preservice teachers’ conceptual understanding of mechanical wave. The findings showed that preservice teachers conceptual understanding of mechanical wave is poor, this in agreement with previous research efforts.
References


THE AIM OF THIS RESEARCH

The aim of this research is to find out what alternative conceptions (misconceptions) American students from 1888 to 1950 had about the preparation and properties of the halogens and their compounds. The research on student alternative conceptions for the halogens has yet to be completed. It will consist of examining my collection of 362 American laboratory manuals which were owned by school and college students. The collection has been made by purchasing laboratory manuals sold by book dealers and on Ebay. The majority of these manuals relate to chemistry and consist of some student answers to questions set by the manual’s author. Reference is made to earlier research by Alex Johnstone (Johnstone, 2006) and to ten papers by the author of this study that relate to student alternative conceptions about physical and chemical change, the preparation and properties of oxygen, the preparation and properties of hydrogen and the preparation and properties of carbon dioxide. The author’s aim in presenting this paper will be to add to the limited amount of research into student alternative conceptions on a historical basis. In his research, Alex Johnstone’s theorises that the students’ lack the working memory space when working at three conceptual levels of chemistry can be a cause of student alternative conceptions. When using student manuals in this historical setting, there are few occasions except writing equations, where the students’ lack the working memory space is put under stress.

The manuals in the collection are mainly chemistry manuals but there are a few manuals of other science subjects such as physics, biology, general science and physiography. Manuals fall into two main categories:

i) Manuals designed for student input
ii) Manuals not designed for student input i.e. there is no room for students to answer questions in the book. Here students use notebooks to write their answers.

METHODOLOGY

1. Examine each manual starting at # 1. If there is no student input move on to next manual.
2. Check to see if the manual contains student input that relate to the preparation and properties of carbon dioxide, carbon, carbon monoxide, carbonates, hard and soft water, water-softening,
baking powders and fire-extinguishers. Record the number of the book and the numbers of the pages examined in a tabular format.

3. Check the material recorded in the table to see if it contains alternative conceptions or misconceptions. Make a record of these and progress to the next manual.

COMMENTS ON METHODOLOGY

1. The collection has been assembled over time so even with manuals designed for student input, some students have not done much work.
2. The early experiments in the manuals are attempted more frequently than the later experiments.
3. The halogens are considered quite late in most manuals, so they may only be attempted by comparatively few students.
4. Students do not answer all parts of questions set by the author. Sometimes good students who try to complete all parts of all questions will appear to have more misconceptions than those who fail to answer questions, leaving blanks. Failure to answer a question is not considered to be a misconception.
5. There is a tendency for many students to give equations as the answers to questions rather than giving full answers. This will probably be reflected in the results.
6. Occasionally, other student comments, comments in manuals not designed for student input and teacher’s marking of manuals will be reported.

METHODOLOGY: ENCOURAGEMENT FROM AN EDITORIAL

The editorial in the Australian Journal of Education in Chemistry in 2006 when introducing the article ‘Children’s alternative conceptions of physical and chemical change obtained from historical sources compared with those found in other recent studies’ gave the following opinion:

A most unusual chemical education research methodology is described by THE AUTHOR. He has investigated student conceptions of the notions of chemical and physical change by interpretation of their notes in laboratory manuals, purchased from book dealers and online sources, that were used in the U.S.A. in the period 1890 to 1950. He looks for ways of thinking that are parallel with alternative conceptions (or misconceptions) identified by recent researchers. Some of the problems associated with this retrospective study of laboratory manuals are discussed. Obviously, the method does not lend itself to defining in advance specific concepts: one is limited to those concepts that students have chosen, or are required, to discuss. The paper has interesting insights into the changing nature of teaching materials over the decades. (Editorial, 2006)

Because of the encouragement from this editorial, I have expanded the size of the collection over the past decade and have also expanded the range of topics investigated.
RESULTS

There are 362 books / manuals/ notes in the collection. Results when complete will indicate how many of the manuals contain information written by students about the halogens and related topics and how many of them have alternative conceptions (misconceptions) about the halogens. Misconceptions by each student about the halogens will be recorded. In previous research on student misconceptions about oxygen, hydrogen and carbon dioxide, the clear majority of these misconceptions related to equations. It will be interesting to see whether or not student misconceptions about the halogens follow this pattern. The full results for each manual investigated will be available in the paper together with an analysis of these misconceptions.

CONCLUSION

Previous research in this area shows the main misconceptions held by students as indicated by the laboratory manuals analysed related to equations. These results appear to be consistent with Alex Johnstone’s theories.

REFERENCES

EXPLORING PHYSICAL SCIENCE TEACHERS’ IDENTITY IN THE CONTEXT OF AN INTERVENTION
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Abstract
This paper reports some results from one aspect of an ongoing study. Teachers in the study participated in an intervention that sought to provide them with skills and knowledge which were essential for conducting science experiments in schools. While there are about 60 teachers participating in the larger study, for this paper, data was gathered from eight teachers through teacher reflections on their participation and classroom observation to corroborate their reflections. Data was analysed both inductively using the grounded approach method and deductively using theoretical resources from Wenger’s Community of Practice perspective. Results of the analysis revealed that participation in the intervention was positively related to shifts in teachers’ identities as physical science teachers. Both analysis of teacher reflections and classroom observation data support the results.

Introduction
Engaging teachers in a continuous teacher professional development is considered a possible solution to most ailing education systems (Whitehurst, 2002). These are systems where large sums of money are invested and yet the returns do not add up to the desired educational outcomes. Most reports of research on education revealed how South Africa’s education system in general and learners in particular, are under achieving when compared to their international or regional peers (see Spaull, 2011). There is even a perception that South Africa’s learners appear to be a Grade level below their peers. South Africa’s educational setbacks have been attributed to several factors including effects of apartheid era, socio-economic status of majority of learners, under resourced schools, and limited teacher knowledge due to the presence of some under trained or under qualified teachers in schools (Venkat & Spaull, 2015). This paper is derived from a larger study which tracks teachers who are participating in a continuous teacher professional development. The goal of the intervention is to help teachers learn skills that are critical for conducting science experiments in the laboratories with learners. The intervention was a Department of Basic Education funded intervention organised for teachers in one province. The aim of the intervention was to train teachers on how to use new science laboratory equip and use it schools. The need for the intervention was prompted by teachers’ complaints that they were not able to conduct science experiments due to old and malfunctioning equipment. Thus an intervention was organised to train teachers on the use
of the state of the art laboratory equipment. The research question was framed as: What is the nature of teachers’ identities following participation in the intervention?

**Literature Review**

The paper draws largely from Wenger’s (1998) notion of Community of Practice with particular focus on the notion of identity. Several scholars have described or defined the word identity as used in the context of teaching. Johnson (1996) defines teacher identity as “a construct, mental image, or model of what being a teacher means” (350). For Johnson (1996), teacher identity guides what teachers should do so as to successfully actualise themselves as teachers. Pennington (2002) and Pennington and Richards (2016) have categorized teacher identity into social identity and professional teacher identity. Social identity is defined as a part of the social context the person lives in and is where the concept of self develops with communication with others, during which the self learns about the roles of others. On the other hand, Sachs (2005) asserts that “teacher professional identity stands at the core of the teaching profession. It provides a framework for teachers to construct their ideas of how to be, how to act and how to understand their work and place in society. Most importantly, teacher identity is something that is not fixed nor is it imposed; rather it is negotiated through experience and the sense that is made of that experience” (Sachs, 2005, p. 15). All the above assertions about identity or teacher identity were considered relevant to the pursuit and focus of this paper.

It is evident here that teacher identity is not static as it continually changes depending on the kinds of experiences that the teacher encounters in both his social and professional work of teaching. This therefore, seems to imply that all teachers need to have a teacher identity in order to improve teaching quality and to increase opportunities for learning to take place in their classes. This implication is directly derived from Johnson’s (1996) assertion that teacher identity directs what teachers should do and how they should do in order to produce the desired educational outcomes. The above seems to suggest that enhancing teacher identity might be a productive way to improve teaching quality in the classroom.

Theoretical resources that framed the study were recruited from situated perspectives with particular focus on Wenger’s (1998) Community of Practice (CoP). The CoP is a theory of learning that says learning is a consequence of participation in a community in which there is shared repertoire, and meaning. The theory also asserts that increased participation in community activities provides the new member with opportunities to progressively move from the periphery to the centre of the community with possibilities of becoming more knowledgeable with continual participation. The outcome of participation might lead to change in the member’s identity. Essentially, a change in identity presupposes that the member has appropriated shared communal practices including new meanings, skills and/or knowledge.

**Methods**
The study adopted an interpretive qualitative paradigm in both data collection and analysis. Participants in the study were eight physical science teachers who were participating in the intervention. Data was captured through teachers’ reflections and classroom observations which were conducted at the end of the intervention. Data analysis was conducted both inductively and deductively (Creswell & Creswell, 2017; Creswell, Hanson, Clark Plano, & Morales, 2007). In particular, grounded theory approach was used to carry out inductive analysis and Wenger’s notions of participation and identity were used in the deductive analysis.

Results

Preliminary results of the study have revealed shifts in teachers’ identities with respect to what they say they could not do before and what they can do after participation in the intervention. These results are supported by analysis of classroom observations data which appears to support teachers’ reflections. As such, there seems to be a relationship between participation in the intervention and shifts on teachers’ identities with respect to their knowledge, skills and ability to conduct science experiments in the classroom.

Conclusion

The results of study seem to support the view that providing continuous professional development might be a possible solution to the challenges associated with under achievement in the South African education system. The study seems to illuminate that teachers do learn in professional development that is continuous, focused on the teachers’ practice and using content from the school curriculum. In response to the research question guiding the paper, it seems that teachers’ identities is shifting towards the centre of the community and this is evident in how they position themselves with regard to what they are able to do. In Wenger’s terms, teachers are beginning to participate in the shared repertoire which is critical for shifts in identity. As already mention, the study is ongoing and so it will be important to understand the nature of teachers’ identity when the larger study is complete. While it is clear that further identity development will take place in the intervention and actual practice later on, a teacher professional development programme seems to be the ideal starting point for instilling not only an awareness of the need to for teachers to develop strong physical science teacher identity, but also a strong sense of the ongoing shifts that will occur in that identity.

References


LEVERAGING LANGUAGE/S FOR ACCESS AND EQUITY IN MULTILINGUAL SCIENCE CLASSROOMS
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Abstract
This paper outlines some of the linguistic challenges faced by teachers and learners in multilingual science classrooms in South Africa. A brief overview of the literature supporting the view of learners’ home languages as resources for learning is provided. An argument is made for the introduction of a module for pre-service science teachers to address these challenges so that teachers are able to proactively engage with and leverage learners’ home languages for science teaching and learning.

Introduction
It is well known that South African learners perform well below the levels of their counterparts in other parts of the world in mathematics and science – as is evident in successive TIMSS and SACMEQ results. This is cause for ongoing concern and has negative implications for knowledge development and national economic growth. One of the contributing factors that has been identified in the TIMSS reports is that of the language medium when this is not the home language of the learners (Howie, 2000; Reddy, 2006). As Reddy (2006) has noted, it is difficult to disentangle the language medium from other co-occurring factors such as teacher knowledge and socio-economic status; nevertheless, research has shown that after poverty, the language medium when learners learn through the medium of their home language is the greatest predictor of academic success (Spaull, 2013).

There is much literature on learning science in linguistically homogenous environments and the challenges that the particular language of science poses for learners: as Martin (1990) has noted, the particular discourse of science is lexically dense, it employs many unfamiliar technical terms, it assigns particular scientific meanings to everyday terms; it makes use of grammatical structures such as the passive voice; and science knowledge is expressed through particular academic genres such as procedures, explanations, reports, arguments.

In the multilingual context of South Africa, English is the home language of only 10% of the population, yet is the chosen language of learning and teaching for the majority of learners from Grade 4 on. However, many learners have not acquired the necessary proficiency in English by Grade 4 in order to successfully access the curriculum and so this poses an added layer of language difficulty in learning science. Thus, science teachers are faced with the dual challenges of teaching science and teaching English, and the unresolved tension between these two objectives.
Many teachers respond to such challenges by switching to the learners’ home language/s when teaching in order to provide epistemic access and for affective purposes. Although the consensus amongst researchers is that such practices are pedagogically sound, education authorities have tended to adopt negative attitudes towards the use of the learners’ home languages in classrooms and consequently such practices by teachers are frequently covert and conflicted.

In several small-scale research projects, science teachers claimed that they had not received any pre-service training in how to teach through the medium of English where it was not the home language of the learners they were teaching. Therefore, it seems timely that training for science teachers should be developed to raise awareness of the role of language in learning and constructing science knowledge; and how to systematically leverage the linguistic resources that learners bring with them to the science classroom in order to open up access and address issues of equity and social justice.

**Literature review**

Recent writing in the field of bilingual education has challenged the monolingual assumptions underpinning the notion of bilingualism as the sum of two separate languages or ‘two solitudes’, as Cummins put it (Cummins, 2008, p. 588), but has instead taken the view that languages comprise a common linguistic resource that can be drawn on flexibly, including in classrooms. Accompanying this has been an acknowledgement of ‘the fluid ways in which languages are used’ in multilingual contexts – what Garcia (2009) has described as ‘languaging’ (p. 23) and ‘translanguaging’ when it refers to moving between languages (see also for example Canagarajah, 2011; Creese and Blackledge, 2010; Makalela, 2015; McKinney, 2017).

These ideas have parallels in the South African context with proposals for a ‘modified dual medium’ multilingual model made by Heugh (1995) in which she suggested that ‘teachers need to be flexible about when and where they alternate between the two languages of learning’ (p. 85). Unfortunately, the models for bilingual education proposed by Heugh and others (see Heugh, Siegruhn & Pluddemann, 1995) have not been taken up by education authorities in South Africa.

Cummins has contributed the idea that language skills and ideas learned in the learner’s home language, can be transferred across languages to the additional language (Cummins, 2000, 2007):

(W)hen students’ L1 is involved as a cognitive and linguistic resource through bilingual instructional strategies, it can function as a stepping stone to scaffold more accomplished performance in the L2 (2007, p. 238).

Thus, classroom translanguaging practices have come to be regarded as not only mirroring the authentic language practices outside the classroom, but also as cognitively sound practices within classrooms.
The consensus appears to be that although codeswitching is a common practice in bilingual classrooms, it is rarely a pre-determined teaching and learning strategy (Adendorff, 1996; Baker, 2001, p. 279; Clegg & Afitska, 2011; Ferguson, 2003; Probyn, 2001), but rather a ‘pragmatic response to the local classroom context’ (Blackledge & Creese, 2010, p. 203); and so there have been calls for such flexible bilingual language use to be developed into a systematic and planned pedagogical strategy and for such language strategies to be included in teacher training programmes (Alidou & Brock-Utne, 2011; Benson, 2004; Ferguson, 2009; Probyn, 2006; Setati et al, 2002).

Proposed intervention/methodology

The proposed intervention is that a module be developed to introduce education students to key ideas relating to language and teaching science in multilingual contexts and to explore the development of systematic and flexible teaching strategies that engage with learners’ linguistic resources to support epistemic access and opportunities to learn science.

The intervention will follow an action research cycle of implementation, reflection and adaptation. It is proposed that a sample of the newly qualified science teachers should be tracked through their first year of teaching, to assess the impact of the language for science teaching module on their teaching practice and what further support and training might be required.

It is hoped that this intervention might feed research observations and findings in the field of teaching science in multilingual contexts, back into classroom practices of science teachers and so address some of the long-standing linguistic challenges facing South African learners.
ENHANCING GRADE 9 LEARNERS’ AWARENESS ABOUT INDIGENOUS KNOWLEDGE BENEFITS IN ENVIRONMENTAL SCIENCE TEACHING AND LEARNING

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Abstract
This paper looks at those challenging aspects of Indigenous Knowledge (IK) that grade 9 learners’ struggle with to make a relevant social-and cultural connection when engaging with environmental science concepts in an environmental science classroom. Focusing on the Western Cape Province in South Africa, and using a quasi-experimental research design model, the study employed both quantitative and qualitative (mixed methods) to collect data in a public secondary school in Cape Town. The study employed a dialogical argumentation instructional model (DAIM) to explain and administered the Views on Indigenous Knowledge Questionnaire (VIKQ) intervention. The interventions used in the study aim to help learners develop informed views of Indigenous Knowledge Nature of Science (IKNOS) in a classroom pedagogy related to environmental science education. Learners from two groups were exposed to a Conception of Weather & Indigenous knowledge Questionnaire (CoW-IQ) evaluation before and after the VIKQ intervention. The results from the two groups were then compared and analysed according to the two theoretical frameworks that underpin the study namely: Toulmin’s Argumentation Pattern - TAP (Toulmin, 1985/2003) and Contiguity Argumentation Theory - CAT (Ogunniyi, 2007b).

Introduction

This study aims to (a) analysis the challenges of the Views of Indigenous Knowledge Questionnaire (VIKQ), which in conjunction with focus-group interviews aims to provide meaningful assessments of learners' IKNOS views; (b) outline the IKNOS framework that underlies the development of the VIKQ; (c) present evidence regarding the validity of the VIKQ; (d) elucidate the use of the VIKQ and associated interviews, and the range of IKNOS aspects that it aims to assess; and (e) discuss the usefulness of rich descriptive IKNOS profiles that the VIKQ provides in research related to teaching and learning about IKNOS. Due to space constrains in this writing, the author will provide a full analytical analysis of the above aims in a publish article at a later stage.

Conceptual and Theoretical Framework

The study is underpinned by an Argumentation Framework based on Toulmin’s (Toulmin, 1985/2003) Argumentation Pattern (TAP) and Ogunniyi’s (Ogunniyi, 2007b) Contiguity Argumentation Theory (CAT). The two theories accord with Vygotsky’s notion of constructivism (Vygotsky, 1978) whereby
an individual learns or acquires new experiences from his/her interactions with his/her physical or socio-cultural environment. The TAP construes learning as a “product of self- or cross-conversation and reflection” (Ogunniyi, 2011a). This study explores the application of both TAP and CAT in the context of classroom discourse dealing with selected meteorological concepts.

**Toulmin’s Argumentation Pattern (TAP) and Contiguity Argumentation Theory (CAT)**

In order to participate in a scientific community, students and novices need to know “how to construct substantive arguments to support their” position (Toulmin, 1985/2003). Toulmin (1985/2003) developed the Toulmin’s Argumentation Pattern, a theoretical model that can be used “as a basis for characterizing argumentations in science lessons” (Ogunniyi, 1997). Toulmin (1985/2003) also suggested that a substantive argument requires providing supporting data to a claim. In the current research study this model was used to compare and analyse the cognitive understandings of grade 9 learners in terms of their conceptions of selected meteorological concepts.

I would argue that as useful as the Toulmin Argumentation Pattern is in assessing the quality of arguments, subsequent research (Le Grange, 2004; Ogunniyi, 2011a) found that it does not address metaphysical IK-rated beliefs that impinge on, or could enrich, learners’ understanding of diverse phenomena. It was because of this limitation that Ogunniyi (2007a) proposed the Contiguity Argumentation Theory.

**Sampling and Data Collection**

The study is based on a *quasi-experimental* pre-post test research design. Random sampling was use to select two grade 9 classes from the same school from a Christian and Islamic religious background. Participants ranged from 14-16 years of age, consisted of 18 learners per group, 9 boys and 9 girls for comparability between the experimental group (E) and control group (C). The two diverse groups were two intact grade 9 classes, 80% being Coloured and 20% African learners from the same community. Both classes were taught by the same educator who was assigned in the study to teach the C group. This class teacher was trained in the IKS/Science based approach and was made aware to keep all content close to the meteorological topics as set out in the Natural Science curriculum. The intervention referred to as (X) focused on the Experimental (E) group only. The Views on Indigenous Knowledge Questionnaire (VIKQ) was the intervention and based on local indigenous knowledge examples of weather prediction (Riffel, 2014). The Dialogical Argumentation Instructional Model (DAIM) class room model was applied in the teaching part of the intervention to the E group. The Control (C) group only received a pre-post CoW-IQ test with no intervention — comparison of the (pre-and-post) CoW-IQ results from both the E and C groups were coded (see Table 1) analyzed in order to establish whether the intervention applied had been successful.

**Data Analysis Method**

Ensuring consistency in the coding and evaluating of the participants data —the respective responses were coded according to a rubric as guideline, rubric values was related to responses on the
questionnaire and coded with a related weight attached as: a informed view (2), partially informed view (1) or an uninformed view (0) on indigenous knowledge—each attached weight was used to calculate the average overall score and round-off to indicate the perceived view as seen below in Table 1.

Table 1. Example of coded results on the CoW-IQ test

<table>
<thead>
<tr>
<th>Participant</th>
<th>Overall score</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Q6</th>
<th>Q7</th>
<th>Q8</th>
<th>Q9</th>
<th>Q10</th>
</tr>
</thead>
<tbody>
<tr>
<td>L001</td>
<td></td>
<td>I</td>
<td>PI</td>
<td>I</td>
<td>UI</td>
<td>I</td>
<td>PI</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>Weighting</td>
<td>2</td>
<td></td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2 (1.6)</td>
</tr>
<tr>
<td>L002</td>
<td></td>
<td>UI</td>
<td>UI</td>
<td>PI</td>
<td>PI</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
<td>PI</td>
<td>I</td>
</tr>
<tr>
<td>Weighting</td>
<td>0</td>
<td></td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1 (1.3)</td>
</tr>
</tbody>
</table>

Q = Question; N/A = not answered; UI = uninformed view (0); PI = partially informed view (1); I = informed view (2)

Findings

The CoW-IQ questionnaire indicated that the learners had little knowledge about IKS and the nature of the impact they have on the local and global community. It appeared that very little indigenous knowledge as such was made use of at home by parents and other family members. If any IKS knowledge was used in daily traditions or practices it was never noted as such by those elders and others as belonging to a cultural system of IK. From this one could assume that it was very difficult or even impossible for learners to be acquainted with the nature and content of cultural knowledge or of IKS when answering the CoW-IQ questionnaire.

Conclusions

Much of the traditional/cultural knowledge is derived from elders in the sample communities. Some (very little) of the cultural-traditional knowledge has made its way into present day situations through ceremonies, stories and folk-lore passed on through traditional dances, song, rituals and other cultural engagements such as community festivals, weddings, prayer meetings and seminars (Riffel, 2011, & 2014). According to Jegede (1996), prior knowledge is related to the environment and in fact an aspect of it. He further asserts that, the environment could be geographic, domestic or socio-cultural and that, “the two are inseparable with the latter creating and nurturing the former” (Gunstone & White, 2000).

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MISSING CONCEPTS IN STUDENTS’ UNDERSTANDING OF ADAPTATION AND NATURAL SELECTION, BEFORE AND AFTER LEARNING ABOUT NATURAL SELECTION

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Understanding science is important for scientific literacy – the ability to apply correct scientific knowledge in our everyday lives, or in careers, to improve the quality of lives. Because an understanding of evolution is central to understanding most biological processes and phenomena, understanding evolution-related concepts is critically important for scholars and members of the public if they are to be considered scientifically literate. This paper describes the nature and extent of the understanding 90 South African Grade 12 scholars from three schools, in terms of adaptation and natural selection, both before they start learning about natural selection in matric, and after having completed that section of work. Attention is focussed particularly on concepts missing from the explanations, as this will help teachers to refocus their notions about teaching the topics.

MOTIVATION FOR THE STUDY

The importance of developing scientific literacy is emphasised by educators worldwide (De Boer, 2000) and is targeted in the South African Life Sciences curriculum (Department of Basic Education, 2011). Scientific literacy involves “developing the ability to creatively utilise sound science knowledge in everyday life or in a career, to solve problems, make decisions and hence improve the quality of life” (Holbrook & Rannikmae, 2009, 281). Understanding evolution is crucial for scientific literacy because it provides an explanatory framework that brings “great order and coherence to our understanding of life”, and because evolutionary biology has important applications in our everyday lives, such as in agriculture and health matters (National Academy of the Sciences, 1998, 3).

Little is known about South African students’ understanding of adaptation and natural selection when they enter Grade 12 (where evolution makes up 23% of the final matric mark), or the effect on students’ understanding of being taught the topics. In spite of the importance of evolution for scientific literacy, research internationally shows that these concepts, and the relationships between them, are poorly understood (e.g. Clough & Wood-Robinson, 1985; Cunningham & Wescott, 2009; Yates & Marek, 2015).

AIM OF THE PAPER

This paper reports on the nature and extent of students’ understanding of adaptation and natural selection, both before and after they are taught about natural selection in Grade 12. Such information
is needed to plan appropriate teaching strategies for teaching natural selection and adaptation, and for developing appropriate curriculum support materials. Particularly important is to identify essential key concepts that are missing from students’ explanations.

**CONCEPTUAL FRAMEWORK**

Lexical problems (Rector, Nehm, & Pearl, 2013) provide obstacles to understanding the concepts evolution, natural selection and adaptation and the links between them. A coherent understanding of how evolution operates helps students develop the mental model essential for meaningful learning. Key to helping students construct the mental model is the relationship between evolution, natural selection and adaptation.

The multiple meanings of the three terms tend to impede understanding of the concepts. All are paradoxical jargon terms that have different meanings in different contexts (Ryan, 1985). Particularly problematic is that evolution is used in different ways in everyday English and in various science disciplines. In biology, evolution refers to “change in the properties (allele frequencies) of groups of organisms over the course of generations” (Futuyma, 2009, 2). The primary cause of evolution is the process of natural selection, and when populations evolve to become suited to their niche, natural selection results in adaptation.

The multiple meanings of adaptation in biology cause further problems (Ashelford, 2002; Ghiselin, 1966). In biology, adaptation can refer to either a product (a characteristic of an organism that increases its fitness) or the process by which populations increase in fitness relative to their environment (Levine & Miller, 1994). This can lead to conceptual difficulties for students, many of whom tend to believe that individuals, rather than populations, adapt (Gregory, 2009). An additional cause of conceptual difficulties for students is the tendency to use the word adaptation to refer to physiological changes that occur during an organism’s lifetime (e.g. acclimatising to altitude). Such changes are not genetically controlled, and are not part of natural selection leading to evolution changes. A number of authors (e.g. Ashelford, 2002; West, 2006) argue that a clear distinction should be made between terms used to describe evolutionary changes (that occur over generations) and physiological changes (that occur in a few days or weeks). West (2006) refers to the changes that occur within populations over generations as “evolutionary adaptations” and the changes that occur in an organism’s body during acclimatisation as “physiological responses” (West, 2006, p. 26), which could eliminate at least one of the lexical problems associated with the term adaptation.

**RESEARCH DESIGN AND METHODS**

The sample: Ninety Grade 12 Life Sciences students from three private schools (n=16, n= 34, n=40) formed the sample for the study. Written consent (their own and their parents’), and completion of both pre- and post-instruction diagnostic activities, were prerequisites for analysis.
**The instrument:** Students answered a four-question written diagnostic activity before and after they were taught about natural selection in Grade 12. Two questions required explanations of the meanings of adaptation and natural selection, and two required application of knowledge of adaptation and natural selection to two unfamiliar scenarios in which animal populations had evolved. To reduce chances of the ‘practice effect’, where students may have discussed their answers or ideas with their friends (Gardner, Schafe, Thein, & Watterson, 1975), two different but equivalent scenarios were used for the post-instruction activity.

**Data analysis:** Open coding (Strauss & Corbin, 1990) was used to identify emerging themes, which were categorised, named, reviewed, and revised as data was analysed. Both authors coded the data before comparing the coding. Discrepancies were discussed and resolved to obtain 100% inter-coder reliability. Six key concepts for the two ‘explanations’, and eight for each ‘scenario-based question’, were identified and face validated by three university biology lecturers who taught evolution courses. Key concepts are statements considered to be essential for demonstrating a full understanding of a term. Understanding was ‘scored’ and ‘missing concepts’ identified. Statistical significance of pre-teaching and post-teaching differences was determined using paired t-tests for mean scores and McNemar’s chi-squared for specific statements.

**Ethics:** All standard ethical guidelines were followed: obtaining permission from school principals and teachers; full disclosure to potential participants; explaining that the study was voluntary; guaranteeing confidentiality and anonymity; and obtaining written consent from students and parents.

**Research rigour:** To improve validity, the instruments went through iterative cycles of critique and modification before being face validated by experts, and the pre-instruction instrument was piloted. Furthermore, guidelines were given to each class teacher to standardise administration of the instrument. Data capture was checked by the second author for accuracy, as were the eventual frequency counts. The coding schemes developed were face validated at all stages of development, and the memoranda face-validated by two additional independent ‘evolution’ academics. Inter-coder reliability was used, as explained earlier.

**RESULTS AND DISCUSSION**

The results and discussion first focus on the extent of correct answers, and then move on to look at ‘missing concepts’, as these are clearly important targets for anyone having to teach about evolution.

**Correct statements in students’ answers**

Table 1 summarises the performance of the group before and after learning about natural selection, using mean scores for the whole diagnostic activity and for each question, and indicates the statistical significance of pre- and post-instruction differences.
1) In spite of having covered the topic of adaptation in four earlier grades, this group of students had a poor understanding of adaptation, and made only small (non-significant) improvements after learning about natural selection in Grade 12 (p=0.28).

Table 1: Frequency of correct statements, by question, for pre-and post-instruction answers

<table>
<thead>
<tr>
<th>Question</th>
<th>Pre-instruction</th>
<th>Mean correct statements per student</th>
<th>Post-instruction</th>
<th>Mean correct statements per student</th>
<th>t-test</th>
<th>p =</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max. possible score</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comprehension-level questions (explanation of terms)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. adaptation</td>
<td>6</td>
<td>1.33</td>
<td>1. adaptation</td>
<td>1.41</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>2. natural selection</td>
<td>6</td>
<td>0.14</td>
<td>2. natural selection</td>
<td>0.76</td>
<td>0.004x10^{-5}</td>
<td></td>
</tr>
<tr>
<td>Total: explanations</td>
<td>12</td>
<td>1.47</td>
<td>Total: explanations</td>
<td>2.17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Application-level questions (scenarios)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. moth</td>
<td>8</td>
<td>1.22</td>
<td>3. beetle</td>
<td>2.24</td>
<td>0.003x10^{-2}</td>
<td></td>
</tr>
<tr>
<td>4. elephant</td>
<td>8</td>
<td>0.57</td>
<td>4. seal</td>
<td>1.92</td>
<td>0.001x10^{-6}</td>
<td></td>
</tr>
<tr>
<td>Total: scenarios</td>
<td>16</td>
<td>1.79</td>
<td>Total: scenarios</td>
<td>4.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean correct statements: total</td>
<td>28</td>
<td>3.26</td>
<td>Total</td>
<td>6.33</td>
<td>0.034</td>
<td></td>
</tr>
</tbody>
</table>

* statistically significant at p = 0.05 level

2) The students had a relatively worse pre-instruction understanding of natural selection than adaptation, although 63% of the students said they had learned about natural selection in an earlier grade. Claims of students having difficulties have been made elsewhere in the world, without giving quantitative data to support the assertion (e.g. Bishop & Anderson, 1990; Coley & Tanner, 2012). Although the mean correct scores improved significantly after learning about natural selection (mean score of 0.14 rose to 0.76 out of a possible 6.8), many students still struggled to grasp the core concepts of adaptation, even after formal instruction on natural selection.

3) Students scored better in the scenario-based application questions than the comprehension-level explanations, even before learning about natural selection, and made significant improvements after learning natural selection, although mean scores were still very low. We have not provided further details, because of the word limit for the paper.

4) Tables 2 (adaptation) and 3 (selection) reveal the extent of the problem relating to specific key concepts. Only the concept of adaptations being suited to the environment was frequently mentioned (about three quarters of the students) (see Table 2). The last three statements on the list were virtually ignored.

In the case of natural selection (see Table 3), five statements were included by only a single student before the teaching of natural selection, although almost two-thirds of the class said they had learned about this topic before. The remaining statement was included by less than 10% of the group.
**Missing concepts in students’ explanations of adaptation**

In order to improve the effective teaching of evolution-related concepts teachers and curriculum developers need not only to know the level of pre-teaching understanding of the students and their post-teaching performance, but also what crucial concepts are missing from their explanations. These need to be targeted to improve teaching and learning of evolution.

Vital concepts were missing from many students’ explanations of adaptation, not only before and learning about natural selection, but also afterwards.

Table 2: Frequencies of missing concepts for explanations about adaptation (n=90)

<table>
<thead>
<tr>
<th>Correct scientific ideas about adaptation</th>
<th>Students with correct and missing statements</th>
<th>chi²</th>
<th>p =</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-instruction</td>
<td>Post-instruction</td>
<td></td>
</tr>
<tr>
<td>Adaptation involves becoming <strong>more suited to the environment</strong></td>
<td>74.4%</td>
<td>25.6%</td>
<td>60%</td>
</tr>
<tr>
<td>Advantageous characteristics convey a <strong>survival and reproductive advantage on individuals with the trait</strong></td>
<td>38.9%</td>
<td>61.1%</td>
<td>25.6%</td>
</tr>
<tr>
<td>An adaptation can also be a <strong>specific advantageous characteristic (feature/ trait)</strong></td>
<td>18.9%</td>
<td>81.1%</td>
<td>36.7%</td>
</tr>
<tr>
<td>Adaptation is a process that occurs by <strong>natural selection</strong></td>
<td>1.1%</td>
<td>99.9%</td>
<td>3.3%</td>
</tr>
<tr>
<td>Adaptation occurs in <strong>populations of organisms</strong></td>
<td>0%</td>
<td>100%</td>
<td>8.9%</td>
</tr>
<tr>
<td>Adaptation <strong>takes many generations</strong></td>
<td>0%</td>
<td>100%</td>
<td>6.7%</td>
</tr>
</tbody>
</table>

* statistically significant at p = 0.05 level

1) Although only a quarter of the students before instruction did not include that *adaptation involves becoming better suited to the environment*, more than 60% excluded the remaining five key-concepts. Disappointingly, 15% more students missed the first two concepts on the list (Table 2) after instruction, although the differences were not statistically significant. Whilst fewer students missed out the remaining four statements, the percentage of the group improving was very low – less than 10% of the group for three of the statements. However, three of the changes, although very small, were statistically significant.

2) The crucially important concept that *adaptations occur in populations of organisms* was not mentioned by a single student before they were taught about natural selection. Several authors point out that adaptation does not occur in individual organisms as students are inclined to think (Clough & Wood-Robinson, 1985; Keskin & Kose, 2015). Many students see physiological “processes” (Ashelford, 2002, p. 98), “adjustments” (Lachmann & Jablonka, 1996, p. 7) or “responses” (West, 2006, p. 26) as being adaptations. Adaptation does not occur to individuals but to populations of organisms. While there was a statistically significant increase in students
mentioning this correct idea (p = 0.005), it was still missing from 91% of students’ answers after instruction.

3) All but one student did miss the vital point that adaptation occurs by the process of natural selection. This may not seem significant, but a number of authors point out that adaptation and natural selection are inextricably linked (Campbell et al., 2015; Futuyma, 2009; Gregory, 2009). It is possible that many of the other concepts missing from students’ explanations are missing because they do not realise that adaptations occur by natural selection. Only two additional students included this point after learning about natural selection in Grade 12, an improvement that was not statistically significant (p = 0.32). The 3.3% of the group that did mention the link is far less than the just over 10% of the 84 12- to 16-year olds in a British study, who had understood adaptation in the light of natural selection (Clough and Wood-Robinson, 1985).

**Missing concepts in students’ explanations of natural selection**

A key reason for students’ poor conceptual understanding of adaptation is their lack of knowledge about its mechanism, natural selection. Table 3 highlights the specific concepts that students struggle to understand before and after learning about natural selection in Grade 12.

1) Students had very little prior knowledge of natural selection, in spite of almost two-thirds of the class having learned about it in an earlier grade. Of the six concepts needed to understand natural selection, five were missing in 98.9% of the students and the sixth was missed by 91.1% of the group. It is an indictment on our education system that students have such a poor understanding of natural selection in their terminal year of schooling. A number of authors argue for an earlier inclusion of natural selection in biology curricula (Kelemen et al., 2014; Pobiner, 2016; Shtulman et al., 2016) because natural selection is the main mechanism by which adaptation and evolution take place, and evolution is a central topic in biology (Campbell et al., 2015; Futuyma, 2009; National Academy of the Sciences, 2008).

2) Table 3 shows that five of the six statements were missing from fewer students’ explanations of natural selection once the topic had been taught. However, only three of the six correct statements showed statistically significant improvements. Even the biggest change (certain variations favour survival in an environment) still left 65% of the group missing this vital concept. The next most-improved statements (there is variation in populations and organisms with favourable variations survive longer, and produce more offspring) still left more than 85% of the students missing the concepts. While teachers need to focus on the concepts that were mentioned least frequently in students’ answers, all six concepts were missed by 73% or more of the students. Therefore, all six key concepts for natural selection knowledge need to be dealt with more carefully by teachers, as very few students seem to be aware of these important points.

<table>
<thead>
<tr>
<th>Correct scientific ideas about natural selection</th>
<th>Students with correct and missing statements</th>
<th>chI²</th>
<th>p=</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-instruction</td>
<td>Post-instruction</td>
<td>Included</td>
<td>Missing</td>
</tr>
</tbody>
</table>

Table 3: Frequencies of missing concepts in explanations of natural selection (n=90)
CONCLUSION

There are several possible factors influencing the poor conceptual knowledge of South African students on these evolution-related concepts. Firstly, no direct link is made between adaptation and natural selection in the South African curriculum statement for Life Sciences (Department of Basic Education, 2011b) and consequently neither textbooks nor teachers realise how important the link is, and fail to emphasise it. Secondly, the curriculum document contains errors, and these are repeated in the textbooks (Tshuma, 2016). Thirdly, teachers have been shown to have poor evolution content knowledge (Ngxola & Sanders, 2009). Finally, students pick up incorrect knowledge from various sources outside the classroom, such as media, parents, and friends (Pobiner, 2016; Yates & Marek, 2015). However, no research has thus far looked at key concepts that are missing from students’ explanations of important evolution-related concepts.

We recommend that teachers focus specific attention upon the vital core concepts that are missing from students’ explanations, and that they emphasise the direct link between evolution, adaptation, and natural selection.

REFERENCES


IS PCK FOR TEACHING CHEMICAL BONDING ONLY POSSESSED BY TEACHERS?

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Introduction

One of Shulman’s most important claims about the construct of PCK is that PCK is uniquely teacher knowledge and can only be developed by a person who is working with content to make it comprehensible to others who are learning a topic (Shulman, 1986). Shulman emphasized that the knowledge of a particular topic possessed by a content expert such as a research chemist is qualitatively different to that of the teacher. For some time now our research group has been designing instruments claiming to be measuring collective PCK (cPCK) of various topics. In earlier work (Rollnick, Davidowitz, & Potgieter, 2017) we showed that there was a difference in certain aspects of organic chemistry but surmised that this may be due to the nature of organic chemistry. In this paper we investigate the contrast in knowledge between chemistry subject matter specialists and chemistry teachers on a different topic which is central to understanding chemistry, namely that of chemical bonding. In this paper we ask the question, “How do the content knowledge (CK) and Topic Specific PCK (TSPCK) of chemical bonding of chemists compare to secondary school teachers?”

Framework for the study

The construct of PCK is well established in the science education research community. As a result of two summits in 2012 and 2016, researchers have come together to create a succession of models of PCK the most recent of which distinguishes collective PCK (collective knowledge held by the community about teaching a particular topic) from personal PCK (the knowledge personalized by an individual teacher for teaching) and enacted PCK (the knowledge a teacher uses in action) (Carlson & Daehler, in press). This paper is concerned with the first of the three constructs and investigates the collective PCK for the topic of chemical bonding, known as Topic Specific PCK, or TSPCK which is PCK within a particular topic (Mavhunga & Rollnick, 2013) It consist of five well-defined constructs namely student’s prior knowledge, curricular saliency, what makes a topic easy or difficult to understand, representations and conceptual teaching strategies. These five components working together within a particular topic constitute TSPCK.

Methodology

In this mixed methods study, we used a previously validated instrument (Toerien, 2017) to measure the TSPCK and CK of chemical bonding of a group of university-based teaching assistants (TAs) and a
group of experienced school teachers. The instrument consisted of two sections – a CK section which interrogated the understanding of respondents and a TSPCK section that was structured according to the five components articulated above.

The instrument as administered to 69 experienced South African teachers and 68 teaching assistants studying for degrees in chemistry at two universities, one in the USA and one in South Africa. The completed instruments were analyzed using a marking memo for the CK and a previously validated rubric for TSPCK, which coded respondents as Limited (1), Basic (2), Developing (3) and Exemplary (4). Scores were validated using inter rater reliability. Once captured the scores were subjected to RASCH analysis using the RUMM2030 programme which places items and persons on the same linear scale, anchoring the item mean at 0.

Findings

The fit of the Rasch model on the whole group was deemed excellent by RUMM with a reliability index of 0.91. However, the item trait interaction as measured by the Chi square function was significant. With the item mean set at zero, the person mean was 0.79 suggesting that the group as found the items as a whole to be relatively easy. The item and person standard deviations were similar at 0.79 and 0.94 respectively. The factor that differentiated teachers from TAs was that of teaching experience. The overall person mean for respondents with no experience was significantly lower than those with teaching experience. Table 1 below shows the means for the various groups.

All the respondents with no teaching experience were TAs

<table>
<thead>
<tr>
<th>Teaching experience (years)</th>
<th>Number in group</th>
<th>Mean overall</th>
<th>Standard deviation</th>
<th>Mean CK only</th>
<th>Standard Deviation CK</th>
<th>Mean TSPCK only</th>
<th>Standard Deviation TSPCK</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>68</td>
<td>0.482</td>
<td>0.71</td>
<td>0.029</td>
<td>0.9</td>
<td>1.00</td>
<td>1.01</td>
</tr>
<tr>
<td>1-3</td>
<td>17</td>
<td>0.662</td>
<td>0.72</td>
<td>0.79</td>
<td>0.79</td>
<td>1.204</td>
<td>0.89</td>
</tr>
<tr>
<td>4-10</td>
<td>17</td>
<td>1.064</td>
<td>1.26</td>
<td>1.22</td>
<td>1.22</td>
<td>1.545</td>
<td>1.52</td>
</tr>
<tr>
<td>11-20</td>
<td>16</td>
<td>1.094</td>
<td>1.25</td>
<td>1.00</td>
<td>1.00</td>
<td>1.545</td>
<td>1.73</td>
</tr>
<tr>
<td>&gt;21</td>
<td>19</td>
<td>1.536</td>
<td>1.54</td>
<td>0.69</td>
<td>0.69</td>
<td>2.012</td>
<td>1.16</td>
</tr>
</tbody>
</table>

Anova Probability  0.000079  0.000008  0.016147

The two item maps generated (figures 1 and 2 in the uploaded document), one for teachers only and one for TAs only, show the differences in order of the item difficulty.

In the case of the teachers, the most difficult items were two content knowledge items (CK2.2 and 2.3) which were well within the person scores for the group, meaning that 33 (just under 50%) stood a greater than 50 % chance of getting these items correct. The two easiest items were both PCK items (CS1 and REP1) which all the teachers stood a greater than 50% chance of being able to do the items.
The most difficult items for the TAs were also CK items (CK5.1, CK 4.2 and CK 4.1). Again these items were within the reach of the whole sample with only three tutors having a greater than 50% chance of getting the items correct (i.e. experiencing the items as easy). A further two had person scores equal to the item score, implying that they had a 50% chance of answering the item successfully. The rest were located below the item score, implying that they experienced the item as difficult. For this group the easiest items were 7 of the 9 TSPCK items, casting doubt on the hypothesis that TSPCK items could only be successfully answered by teachers. It was thus decided to run the RUMM programme again with only TSPCK items for both groups. The run resulted in similar findings, this time with the tutors doing even better and three teachers finding all items difficult.

Figure 1: Item map showing teachers only

Figure 2: Item map showing TAs only

Discussion

While the results for person factors showed that teaching experience was a significant factor in the scores, and that teachers overall had a higher person mean than tutors, the item locations for the two groups did not bring up the TSPCK items as being more difficult for either group, and different items emerged as the more difficult items. These findings will be probed more deeply in the conference presentation showing qualitative findings. However, it is becoming apparent that the CK questions provided a greater than expected challenge for both groups given that they were based on high school content.

References


Toerien, R. (2017). Mapping the learning trajectories of physical sciences teachers' topic specific knowledge for teaching chemical bonding. University of Cape Town,
Research worldwide shows that rejection levels of evolutionary theory are high, knowledge levels low, and that misconceptions about the topic abound. Whilst evolution education is currently probably one of the most prolific fields of science education research, the research tends to be fragmented and piecemeal, and relationships and causal links are not always visualised in a systematic way. This paper proposes a research-based model intended to provide a theoretical framework that 1) teachers can use to more systematically address the problems often associated with the teaching and learning of evolution, and that 2) researchers can use as a basis for focusing research on the broader problem and possible multiple solutions. The model focuses on factors that influence border-crossing from a religious worldview to the worldview of the biology classroom.

PROBLEMS MOTIVATING THE PAPER

Two-and-a-half decades after calls for more research into evolution education (Good, 1992; Cummins, Desmastes, & Hafner, 1994) this has become possibly one of the most prolifically researched topics in science education. Numerous problems identified by researchers motivated this paper, and the research underlying it. Firstly, in spite of the importance of evolution for the understanding of the biological sciences, and its central place in scientific literacy, research has shown that levels of knowledge and understanding of evolutionary theory and its applications in the real world are generally low; that misconceptions about the topic are rife; and that levels of rejection of evolution theory are high (Carroll, 2014; Curry, 2009; Jones, 2011; Miller, Scott, & Okamoto, 2006; Newport, 2012). All three of these problems have been identified within the teaching corps—the very professionals tasked with producing an educated public (Borgerding, Klein, Ghosh, & Eibel, 2015; Molefe, 2013; Ngxola, 2012; Rutledge & Mitchell, 2002; Trani, 2004), as well as in many students at all levels—the people who are meant to develop into the educated public (Blackwell, Powell, & Dukes, 2003; Downie & Barron, 2000; McKeachie, Lin, & Strayer, 2002).

Secondly, although “[e]volutionary biology has been and continues to be the cornerstone of modern sciences” (The National Academy of Sciences, 2008, ix), and is commonly included in school curricula worldwide, some teachers resist teaching it, or teach it at a superficial level, or subject to various stipulations (Berkman, Pachecho, & Plutzer, 2008). Furthermore, a number of students are strongly resistant to learning about it, for a range of reasons. This can make science classrooms stressful places
for both teachers and students, when evolution is taught (BBC News, 2007; Griffith, & Brem, 2004; Schilders, Sloep, Peled, & Boersma, 2009).

Thirdly, whilst the research on evolution education has increased exponentially in the last few decades, studies tend to focused on specific aspects, so the research becomes piecemeal and disjointed. Ironically the research in this field fits the description by Dobzhansky (1973, 129) of biological facts viewed without the explanatory framework of evolution: “a pile of sundry facts--some of them interesting or curious but making no meaningful picture as a whole”. This makes it very difficult for teachers to get a holistic overview of the problems so that they can find a systematic way of addressing them when teaching evolution. Furthermore, some researchers may also be seeing the problems as isolated points of interest, rather than as part of a bigger picture, although many do consider multiple categories of factors (e.g. Denitz, Donnelly, & Yilmaz, 2008; Heddy & Nadelson, 2013; Pobiner, 2016). Several authors have proposed visual models that show relationships between factors (e.g. Denitz et al., 2008, Ha, Haury, & Nehm, 2012). However, research results can be contradictory; the relationships often extremely complex and not well understood (Pobiner, 2016), and because models may focus on the specific aspects that interest the researchers, they may omit other factors that contribute to the bigger picture. In addition, these models are sometimes presented in a way that is not immediately clear to non-researchers (for example, teachers and curriculum developers) for whom they have particular relevance.

AIM OF THE PAPER

The aim of this paper is to suggest a parsimonious but comprehensive, visual, research-based, explanatory model of the complex web of facilitating and impeding factors that affect students as they move into a learning environment dominated by scientific worldview perspectives. Using a grounded theory approach (Strauss & Corbin, 1990), the model emerges from eight South African studies conducted over the past ten years by one research group, and an analysis of decades of international research literature. Although research has been done on factors affecting rejection and acceptance of evolution, and students’ reasoning behind their stance, I have found no comprehensive model of such factors.

THEORETICAL FRAMEWORK

Two main theories underpin the proposed model: the theory of planned behaviour (Ajzen & Madden, 1986), and border-crossing (Phelan, Davidson, & Cao, 1991). People’s worldviews are based on their life experiences, developed in social and cultural contexts, and are used to make decisions about what to believe and how to act on such beliefs (Phelan et al., 1991). These authors recognise that when students from a particular worldview (for example, a religious one) are expected to change to another (such as the worldview of the science classroom), it is akin to crossing the border to a foreign country. Students cope with such border crossings with differing levels of success, which Phelan et al. describe as ‘smooth’, ‘managed’, ‘hazardous’, or ‘unsurmountable’. Some students never manage
to cross the metaphorical border, for a wide range of reasons that teachers need to understand before they can help students. Such students are more likely to perform poorly in evolution courses (McKeachie, Lin, & Strayer, 2002), to have more misconceptions about the topic (Dagher & BouJaoude, 1997; Moore et al., 2006), to experience more stress in class (Schilders et al. 2009), and to drop out of such courses (McKeachie, et al., 2002). Tying into this, the theory of planned behaviour suggests that the way people behave is influenced by their behavioural intentions, in turn influenced by their attitudes, which are swayed by their beliefs. Understanding factors that can mitigate or aggravate border crossing (in terms of acceptance of the validity of evolutionary theory) could help teachers address the problems, and influenced the explanatory model underpinned by these two theories, and presented in this paper.

**THE PROPOSED MODEL**

The model is intended, in as parsimonious way as possible, to convey visually the factors that impact on acceptance of evolution theory (shown in Figure 2), and which of these facilitate and which hinder border crossing (see Figure 1). Central to the model is the separation of factors into a personal milieu and a contextual milieu, so that factors embedded in the cognition of individuals can be more widely recognised as something separated from the well-researched external factors that influence an individual’s beliefs, attitudes, and behaviours.

Factors within the **personal milieu** are shown in Figure 1, and can be seen to follow the theory of planned behaviour (Ajzen & Madden, 1986), which suggests that BELIEFS influence ATTITUDES, and hence BEHAVIOURAL INTENTIONS, which in turn affect BEHAVIOURS (in this case, how people react to the scientific ideas of evolution). Because of the importance of prior learning, a KNOWLEDGE category has been added at the start of the chain. Knowledge and understanding of evolution have been shown to affect acceptance of evolution theory, especially once the multiple types of evidence are known by students.

Researchers recognise the existence of **cognitive** and **affective domains** within the mind of individuals. The cognitive domain includes students’ ideas about the world, whether they are taught to them or are just personal perceptions. The cognitive domain incorporates their KNOWLEDGE and **understanding of evolution** Denitz et al., 2008; Ha et al., 2012, their religious beliefs about creation (Ha et al, 2012), and **their misconceptions** about both evolution and the perceived conflict between evolution and religion. Misconceptions about evolution are prevalent, and they and religious beliefs have both been shown to negatively influence students’ willingness to accept the validity of evolution theory (Dagher, & BouJaoude, 1997; Kagan, 2011). While BELIEFS are part of the cognitive domain, they can be strongly influenced by **attitudes** to learning about evolution. **ATTITUDES** are considered to belong in the **affective domain**, but because attitudes depend so strongly on beliefs, the cognitive and affective domains are represented as overlapping areas in the model. In the affective domain are negatives attitudes to having to learn about evolution, and the tendency of many religious students to reject ideas about biological evolution (Berkman et al., 2008; Ha et al, 2012).
Research investigating the correlation between the several variables and acceptance has identified facilitating and impeding influences, as shown in Figure 1 to the left and right respectively of the backbone of factors from the theory of planned behaviour. In terms of KNOWLEDGE, higher levels of knowledge and understanding of evolution, and higher educational qualifications, improve levels of acceptance. On the other hand, ignorance about evolution, low educational attainment, and fewer years of education all negatively impact on acceptance (Mazur, 2004). In addition, unscientific acquired ideas, and self-constructed misconceptions also decrease the levels of acceptance. In the BELIEFS category, students with creationist beliefs typical of many fundamentalist religions, and biblical literalists, are less likely to accept evolution. ATTITUDES that improve the chances of accepting evolution include open-mindedness (Denitz, et al., 2008; Kagan, 2011), an inquiry-orientated mindset (Kagan, 2011) and trust in science and scientists (Nadelson, & Hardy, 2015). Attitudes negatively impacting on acceptance include dogmatism and distrust of science and scientists. All factors shown on the left in Figure 1 can lead to the intention to accept evolution, especially if evidence is provided. Those shown on the right will decrease intentions to accept. These mindsets will ultimately result in actual BEHAVIOURS (acceptance or rejection of evolution).

**Figure 1: Facilitating and impeding factors operating in the personal milieu**
Figure 2 shows the complete model, trimmed of excess information to show just the main factors. Important to note is that the personal milieu is embedded in the contextual milieu in which individuals exist and function in their daily lives. The contextual milieu is essentially an educational milieu, in that the factors it contains have some impact on children’s developing ideas, attitudes and behaviours. It is divided into ‘in-school’ and ‘out-of-school’ domains, and the border between these two is where border-crossing needs to occur, particularly in the case of students who may be religious-text literalists. The ‘in-school’ domain encompasses external educational factors (those existing in the environment of the learners) that have a strong impact on students’ views, notably the teacher factor (e.g. their beliefs, attitudes, knowledge, skills, and teaching approaches) and the support materials used for teaching and learning (such as curriculum statements/syllabi, textbooks, old examination papers and memos, etc.). Research internationally, as well as in South Africa, has shown that some teachers have misconceptions about evolution (Molefe, 2013; Ngxola, 2012; Yates & Marek, 2014), may object to having to teach evolution (Trani, 2004), or are apprehensive about having to teach it (BBC News, 2007; Sanders & Ngxola, 2009). These factors influence how and what they teach, and Yates & Marek (2014) have shown that teacher’s misconceptions do get passed on to their students.

Curriculum support materials such as syllabi (Sanders & Makotsa, 2016) and textbooks (Tshuma & Sanders, 2015) have been shown to contain misconceptions, as well as poorly worded statements (latent errors) that could lead to misconceptions. Because South African textbook authors and publishers are compelled to follow the curriculum statements without deviation, errors in the curriculum statements are transferred to, and multiplied in the textbooks (Sanders, & Makotsa, 2016). Furthermore, an analysis of five years of South African matriculation examination papers and
mark memoranda from two examining bodies has also revealed misconceptions (Reddy, 2013). Errors in textbooks and examination papers are likely to have a strong backwash effect on the misconceptions of teachers and students, because such documents are used to study from (Spratt, 2005).

In the ‘out-of-school’ domain two major categories of factors influence a child’s ideas, the parent factor (including their knowledge, beliefs, attitudes, and parenting practices) and the community factor (including religious beliefs and practices, and societal norms and standards). Political affiliations are also important as more conservative groups (parents and the communities) are more likely to reject evolution (Nadelson & Hardy, 2015).

**DISCUSSION**

Of course, reality is “messy” and does not always fit neatly into independent non-overlapping categories (Law, 2003, in the context of research methods). So, some categories overlap the boundary between the ‘in-school’ and ‘out-of-school’ domains. For example, the ideas, attitudes and misconceptions of peers may be spread to their friends both in and outside of the school arena, and community-factors such as religious ideas may act directly on students or through school policies and practices the community influences. The language factor is particularly problematic, overlapping both of the domains in the contextual milieu, as well as the personal milieu. Many important terms used to explain evolution are paradoxical jargon words (Ryan, 1985), which have one meaning in everyday English, and another meaning (often meanings) in biology. For example, evolution in English refers to a slow change in anything, but has a range of meanings in different sciences, including a very specific meaning in biology, that are not compatible with the everyday meaning. The everyday meaning of adaptation has a very different meaning to that in biology, differing in specifics that often lead to misconceptions associated with the ‘evolution on demand’ alternative framework (Jensen & Finley, 1995). Metaphors, such as survival of the fittest and natural selection, cause problems for students who do not realise that they are figures of speech implying analogous relationships, and not literal descriptions (Sanders, 2014).

A further challenge in representing reality in the model is that many of the directional arrows showing which factors influence each other, and the direction of such impacts, could not be shown in the visual model, due to the complex and confusing web that results.

**REFERENCES**


EXPLORING THE FACTORABILITY OF THE NATURE OF SCIENCE CONSTRUCT
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Abstract
The purpose of this study was to explore the factorability of the nature of science construct and assess its validity through factor analysis. The reliability of scores on the questionnaire was good at $\alpha = .87$. The sample of 860 secondary school students in Namibia participated in the study, using the paper-and-pencil method. Exploratory factor analysis revealed a final interpretable five-factor structure consisting of 16 items and the factor solution accounted for 67.73% of the total variance. However, parallel analysis revealed that only four factors had eigenvalues that were statistically significant ($p = .05$). The measurement model was assessed by means of confirmatory factor analysis and the results showed that the model had moderate statistical fit for the data. These findings indicate that the psychometric validity of the eight-dimension model that had been qualitatively suggested could not be confirmed. This could be attributed to the complexity of nature of science construct. However, reasonable construct validity and reliability was observed though some of the model fit indices were lower than the recommended thresholds. Implications for 21st century skills development are discussed.

Keywords: Nature of science; 21st century skills; validity; factor analysis

Introduction
The current over-simplified forms of inquiry make students think of science as the accumulation of simple facts rather than the construction and revision of models and theories about the natural world. In response, there has been a shift of learning goals in recent years, from content knowledge and process skills to understandings of the nature of science and the ability to engage in scientific inquiry. This shift emphasises the epistemic aspect of scientific inquiry needed to help students develop 21st century skills. Students need to develop sophisticated scientific epistemic beliefs in order to understand the nature of scientific knowledge and how such knowledge is constructed (Gu & Belland, 2015). Advancing students' beliefs about the nature of scientific knowledge and knowing has featured prominently in recent research in science education (Chen, 2012; Chen, Metcalf, & Tutwiler, 2014; Conley, Pintrich, Vekiri, & Harrison, 2004; Tsai, Jessie Ho, Liang, & Lin, 2011). However, none of such studies appear to have been conducted in Namibia.
The aim of this research was to explore the factorability of the nature of science construct that is deemed appropriate for students in basic education phase (K-12) as well as to assess its factorial validity. The research endeavoured to answer the following questions:

1. What is the reliability and construct validity of the eight-dimension nature of science-based questionnaire?
2. Is the theorised eight-dimension nature of science construct quantitatively factorable?

Scientific epistemic beliefs are individual domain-specific beliefs about scientific knowledge and the acquisition of such knowledge. These beliefs have an important role in several aspects of academic learning and achievement as well as the development of 21st century skills (Leal-Soto & Ferrer-Urbina, 2017; Paechter et al., 2013).

**Theoretical background**

Nature of science is described as “the epistemology and sociology of science, science as a way of knowing or the values and beliefs inherent to the development of scientific knowledge” (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002, p. 498). With regards to this view of science epistemology, students should develop beliefs that scientific knowledge: 1) can change over time (tentative) 2) empirically-based (based on observations of the natural world) 3) there is no one way of doing science called “the Scientific Method” 4) subjective 5) influenced by imagination and creativity 6) socially and culturally embedded 7) observation and inference are different and 8) theories and laws are distinct kinds of scientific knowledge (Abd-El-Khalick et al., 2017; Abd-El-khalick & Lederman, 2000; Chen, 2012; McComas, 2008; Niaz, 2008; Osborne, Collins, Ratcliffe, Millar, & Duschl, 2003). This suggested eight-dimension construct though validated through a solid interpretivist approach, its validity has not been demonstrated psychometrically, thus inhibiting the confidence in its use.

**Methodology**

A questionnaire based on the eight general dimensions of nature of scientific knowledge as proposed by Lederman and others (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Lederman & Abd-El-Khalick, 1998; McComas, Almazroa, & Clough, 1998, Lederman et al., 2014) was used. Respondents were required to give their personal level of belief or agreement with the five-point Likert scale. The statements were also in a form of nuanced beliefs about nature of science. It was administered to a sample of 860 Grade 12 students in Namibia, using the paper-and-pencil method. Data was analysed using Cronbach’s alpha to determine reliability of responses, exploratory factor analysis to assess the nature of science factor structure and confirmatory factor analysis to assess the measurement model fit using the $\chi^2/df$, RMSEA, SRMR, TLI and CFI (Glynn et al., 2011; Teo, 2013). Construct validity was assessed considering two criteria: convergent and discriminant validity (Cristobal, Flavián, & Guinalíu, 2007)
Findings

The reliability of scores on the questionnaire was $\alpha = .87$. To establish convergent validity, factor loadings of indicator variables, composite reliability (CR) and the average variance extracted (AVE) were used (Ab Hamid, Sami & Sidek, 2017). The AVE values for the five factors model ranged from .46 to .64. The CR values ranged from .75 to .81. Although the AVE values for one factor were below the acceptable minimum cut-off point of .50 (empirical = .46) convergent validity may still be adequate because all latent factors had CR values above .70 (Fornell & Larcker, 1981). Discriminant validity was assessed by comparing the square root of the AVE with the correlation of latent factors (Hair et al., 2016). For the five-factor model, although the square root of the AVE for all latent factors were greater than .50, it was not greater than inter-latent factor correlations for all factors. The square root of AVE for subjectivity was less than its correlation to scientific methods. The MSV values for the two factors (subjectivity and scientific methods) were greater that the AVE values which is contrary to recommendations. However, for the four-factor model, all latent factors support the requirements and discriminant validity of all latent factors was adequate, thus construct validity was confirmed.

Exploratory factor analysis revealed a final interpretable five-factor structure consisting of 16 items and the factor solution accounted for 67.73% of the total variance. The five factors retained based on eigenvalues greater than one and the percentage of variance were: empirical (5.49, 34.30%), sociocultural (1.78, 11.13%), subjectivity (1.36, 8.50%), scientific methods (1.19, 7.44%), and tentativeness (1.02, 6.37%). Parallel analysis revealed that only four factors had eigenvalues that were statistically significant for retention at $p = .05$ (O’connor, 2000). Confirmatory factor analysis results showed that the five-factor model had poor statistical fit for the data. However, the four-factor model had better statistical fit for the data, though still below recommended thresholds.

Conclusion

The findings indicate that the psychometric validity of the eight-dimension nature of science that had been qualitatively suggested could not be confirmed. This could be attributed to the inherent complexity of nature of science. However, the theorisation had adequate construct validity and reliability though it had fit statistics lower than the recommended thresholds. It can be concluded that theorisation showed potential to be quantitatively factorable. In the 21st century, every citizen needs to acquire adequate scientific knowledge and skills to be competitive in the job market and to be scientific literate in everyday context. To prepare students to face 21st century challenges, they should develop sophisticated scientific epistemic beliefs in order to understand the nature of scientific knowledge and its development. Although sophisticated beliefs cannot be taught because they ought to develop innately in students, the epistemic climate can be established through teaching and modelling of critical thinking, evaluation of problem-solving approach and making connections to students’ prior knowledge and epistemic virtues.
References


POST GRADUATE CERTIFICATE IN EDUCATION STUDENTS’ TOPIC SPECIFIC PEDAGOGICAL KNOWLEDGE (TSPCK) ON PARTICULATE NATURE OF MATTER

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Introduction

Adequate science content knowledge (CK) is a necessary perquisite for effective teaching of science. Lack of adequate science content knowledge is evident in the pre-service curriculum for teachers teaching grade 10 or earlier grades where learners study natural sciences, a combination of science disciplines including physical sciences, earth sciences and life sciences. Literature shows that many natural science teachers have insufficient CK in some or all of these disciplines (Davis, Petish, & Smithhey, 2006). This paper explores the knowledge in a group of pre-service teachers registered for a postgraduate certificate in education (PGCE) to teach natural sciences, but who do not necessarily possess the pre-requisite content knowledge.

The PGCE programme is premised on the basis that all necessary content knowledge has been acquired by prospective teachers in their undergraduate degree. Thus, the current PGCE programme at the university where this study was done focuses primarily on teaching and learning theories and methodologies, at the expense of subject content knowledge. The students enrolled in the PGCE science programme need to have completed two first level courses in physics, chemistry, life science or environmental sciences. The Natural sciences curriculum requires some knowledge of several science disciplines, which however was not necessarily the case for the pre-service teachers in this study. A particular challenge for the pre-service teachers was their understanding of basic chemistry topics, in particular the particulate nature of matter, which is central to understanding topics that are more advanced. In this study, we investigated the ability of PGCE students to improve their TSPCK and CK of the particulate nature of matter for teaching.

Theoretical Framework

Pedagogical content knowledge (PCK) formed the framework for the current study. According to Shulman (1986), PCK bridges the gap between teachers’ subject matter and their transformation of knowledge into instructional form for students. Competencies are thus an important component of teacher knowledge. TSPCK is PCK within a particular topic (Mavhunga & Rollnick, 2013) and it consist of five well-defined constructs namely; students prior knowledge, curricular saliency, what makes a topic easy or difficult to understand, representation and conceptual teaching strategies. These five components working together within a particular topic constitute TSPCK.
Aims of the study

The purpose of this study is to compare the TSPCK of PGCE students who taught the topic on the particulate nature of matter as part of their teaching experience with those who did not teach the topic. The paper answers the following research questions;
1. What is the quality of PGCE pre-service teachers' understanding of prerequisite CK and TSPCK for the topic on the particulate nature of matter?
2. How does this understanding differ in students who have taught the topic to grade 8 and 9 students?

Method

This paper reports on a mixed method study located within a pragmatic paradigm (Creswell, 2014) with a large group of PGCE students in a South African University. The PGCE is a one-year programme and consists of 16 weeks of direct teaching and further weeks of practice teaching.

Two validated instruments testing CK and TSPCK (Pitjeng-Mosabala & Rollnick, 2018) were employed in the study. The CK instrument tested knowledge of content matter pertinent to the topic at grades 8 and 9 levels while the TSPCK instrument was structured according to the five components of TSPCK. The instruments were administered to the pre-service teachers before and after teaching practice. No specific instruction was given on the topic, but some students taught the topic during their teaching practice while others did not. The process by which they were assigned was out of the control of the university and determined by the schools where they were placed. The participants consisted of 172 PGCE students, 35 with no university level chemistry background; 81 with first year chemistry pass, 27 with second year chemistry and 31 students who had completed third year chemistry.

Results

The CK instruments was marked using a memo and the TSPCK instrument responses were coded using a validated rubric (Pitjeng-Mosabala & Rollnick, 2018) using a scale of limited (1), basic (2), developing (3) and exemplary (4). The ratings were checked through inter rater reliability. Table 1 shows the coding of the TSPCK pre-test.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Students prior knowledge</td>
<td>LPK 1</td>
<td>137</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>LPK2</td>
<td>165</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Curricular saliency</td>
<td>CS1</td>
<td>145</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>CS2</td>
<td>172</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>CS3</td>
<td>170</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>
The results in Table 1 indicate very little pre-existing knowledge on the part of the pre-service teachers on; (1) students’ prior knowledge, (2) curricular saliency, (3) what makes a topic easy or difficult to understand, (4) representation and (5) conceptual teaching. In the current study, the majority of the preservice teachers’ PCK was found to be weak.

It was thus decided to administer a posttest after they returned from school experience to compare the performance of those who had taught the topic with those who had not. This data is currently being collected and analysed and findings will be presented at the conference.

**Discussion**

The findings of the current study show that PGCE natural science students at the entry level did not possess adequate knowledge of TSPCK on the topic on the particulate nature of matter.

The findings by Pitjeng-Mosabala and Rollnick (2018) for a smaller sample of PGCE Teach SA candidates however suggest that the experience of teaching the topic at grade 8 has a positive effect on TSPCK. The teachers in the above study however did undergo a short intervention. There is thus reason to expect better scores in the teachers who have taught the topic. Other studies such as Mavhunga (2016) suggest that an intervention is necessary to ensure transfer of knowledge to other topics.

**References**


A CASE STUDY SURVEY OF A TOWNSHIP SCHOOL SCIENCE STUDENTS’ KNOWLEDGE, ATTITUDES AND PRACTICES OF CLIMATE CHANGE IN SOUTH AFRICA

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Abstract
Climate change, which many studies indicate is largely caused by human activity, is an issue that has solutions that lie in changing the mind set of everyone, more so, the youth. As in other developing countries, climate change as a global phenomenon, is gaining audience in the public domain of South Africa, yet very little seems to be done to mitigate it’s devastating effects. Solutions to address this issue, lie in challenging the existing mind set in societies, hence the importance of quality science education of young people. This article reports on the knowledge of science learners (n=134) in grades 9 – 11 in relation to climate change. Knowledge, together with attitudes, inform peoples’ practices. This research draws data from a broader case study survey which explored science learners’ knowledge, attitudes and practices of climate change in a township school southeast of Johannesburg. The study used a field-tested questionnaire and Aho (1984)’s conceptual framework which links cognitive, socio-emotional and ethical education in the formation of the relationship between man and the environment. Consistent with international literature, the broader study results exposed that even though South African learners show positive attitudes towards climate change, they however, have very limited knowledge of this socio-scientific global issue.

Introduction
Climate change is currently a pressing World-wide problem, as evidenced by droughts and floods devastating some parts of the globe. Research suggests human activities impact negatively on the environment (Chapman & Sharma, 2006). As in other developing countries, climate change as a socio-scientific phenomenon is gaining audience in the South African public domain, yet very little seems to be done in science classrooms to prepare learners in addressing this issue. Climate change is an anthropogenic global issue, calling for concerted efforts from all sectors of the community, and education as a vehicle for any massive societal change, is key. Thus, it is through quality education that people’s perceptions, attitudes and knowledge are changed, as they are, to a large extent shaped by formal curricula. Providing quality science knowledge and changing learners’ attitudes can redress the current negative impact on the environment. Knowledge, together with attitudes, inform peoples’ practices (Aho, 1984) and hence the focus of this study.

Literature Review
Several studies were done in different areas to explore environmental attitudes, perceptions and knowledge in relation to climate change, with Chapman & Sharma (2006) investigating Indian and Filipino primary and secondary school students and Cutter and Smith (2001) that of Austrian primary school teacher’s as a factor that affects capacity of schooling to achieve environmental education goals. Cutter and Smith (2001)’s study revealed that primary school teachers were environmentally illiterate. Gwekwerere (2014) investigated Canadian pre- service teachers’ environmental knowledge, their willingness to participate in environmental initiatives and their perceptions about environmental education in schools where they demonstrated limited environmental knowledge.

Literature (Aho, 1984; Gwekwerere, 2014) on climate change literacy highlights that knowledge alone is critical but not sufficient because lifestyles are driven by certain values and attitudes. Young people in any society, can be a great force to bring change, hence focus on learners in schools (Chapman & Sharma, 2006).

**Conceptual framework**

This research draws data from a broader case study survey which explored grades 9 to 11 science learners’ knowledge, attitudes and practices of climate change in a township school, southeast of Johannesburg. The study used Aho (1984) ‘s conceptual framework linking cognitive, socio-emotional and ethical education in the formation of the relationship between man and the environment, figure 1.

![Conceptual framework diagram](image)

*Figure 1. Connection between cognitive, socio-emotional and ethical education in the formation of the relationship between man and the environment, Aho (1984)*
Aho’s model sees knowledge as being critical because it is interdependent on problem solving skills and thought processes, while at the same time shaping people’s practices. In-depth knowledge of climate change, its facts, concepts and principles, can be used to redress effects it is associated with, after effective comprehension and analysis of the phenomenon. According to Aho, both knowledge and attitudes inform people’s practices.

Methodology

This study used a three sectioned field-tested questionnaire with multiple options as answers to try to gain a more comprehensive understanding of learners’ knowledge. The questionnaire was modified drawing from field tested studies (Esa, 2010 and Gwekwerere, 2014) and piloted with nine science teachers and 20 science learners (Nakedi, 2018). The study used convenient sampling where four classes: two Grade 9 Natural Sciences (n=71), one Grade 10 Physical Sciences (n=33) and one Grade 11 Physical Sciences (n=30) learners participated in the survey. Data collected was then analysed using Likert scale and scoring of knowledge, out of 15 was done.

Results

As will be recalled, the study meant to elicit for learners’ knowledge, attitudes and knowledge they hold in relation to climate change. Table 1 shows knowledge scores.

Knowledge

Table 1. Grades 9, 10 & 11 Knowledge scores out of 15. Mode=3

<table>
<thead>
<tr>
<th>Participant scores out of 15</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants who received the scores</td>
<td>1</td>
<td>8</td>
<td>22</td>
<td>33</td>
<td>28</td>
<td>12</td>
<td>18</td>
<td>9</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

From Table 1 above, learners scored a range of 0-9 with 3 learners scoring above half. Most of the learners scored 3. Only 3 learners out of 134 learners scored above half, thus 2% of the participants scored above half. Graph 1 below shows range and frequency of scores of learners.

Graph 1. Range of scores for knowledge for Grades 9, 10 & 11
Most of the learners scored in the range 0-5, constituting 78%. These learners are not knowledgeable. The mean score for these learners is 3.9.

Questions 2-15 are grouped into different knowledge concepts, thus greenhouse effect, global warming, ozone layer and sustainable development terms.

Table 2. % of correct responses for Gr 9,10 & 11(mean) for knowledge concepts

<table>
<thead>
<tr>
<th>concept</th>
<th>% of correct responses for Gr 9(mean)</th>
<th>% of correct responses for Gr 10(mean)</th>
<th>% of correct responses for Gr 11(mean)</th>
<th>% of correct responses for Gr 9,10,11(mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greenhouse effect</td>
<td>25</td>
<td>34,7</td>
<td>50</td>
<td>36.5</td>
</tr>
<tr>
<td>Global warming</td>
<td>32</td>
<td>15</td>
<td>29,8</td>
<td>25.6</td>
</tr>
<tr>
<td>ozone layer</td>
<td>22,5</td>
<td>18,2</td>
<td>33,1</td>
<td>24.6</td>
</tr>
<tr>
<td>Sustainable development</td>
<td>10,5</td>
<td>53</td>
<td>69</td>
<td>44.2</td>
</tr>
</tbody>
</table>

From table 2 above, Grade 9 & 10 learners have difficulties in comprehending all climate change concepts since the mean is below 50% except for sustainable development in Grade 10.

**Environmental attitudes**

The mean attitude score is 27.6 from a possible 62. Grade 9 learners agree that it is possible to have both a prosperous economy and a healthy environment (33.3% strongly agree & 44.4% agree). Some of the learner’s attitudes towards the environment are summarised in table 3 below.

Table 3. examples of Gr 9, 10 & 11 learners’ responses to actions related to environmental problems

<table>
<thead>
<tr>
<th>Attitude</th>
<th>% strongly agree</th>
<th>% strongly agree</th>
<th>% do not agree</th>
<th>% not sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Our country should concentrate on economic growth</td>
<td>28,2</td>
<td>45,1</td>
<td>16,9</td>
<td>9,9</td>
</tr>
<tr>
<td>Citizens of this country should concentrate on protecting the environment if it means some reduction in economic growth</td>
<td>20,0</td>
<td>54,3</td>
<td>10,0</td>
<td>15,7</td>
</tr>
<tr>
<td>There should be laws to control the cutting down of trees</td>
<td>42,9</td>
<td>25,7</td>
<td>14,3</td>
<td>17,1</td>
</tr>
<tr>
<td>People must be allowed to cut down trees whenever they want</td>
<td>11,1</td>
<td>12,5</td>
<td>72,2</td>
<td>4,2</td>
</tr>
<tr>
<td>People should settle wherever they want including watershed areas and close to rivers</td>
<td>2,8</td>
<td>19,7</td>
<td>60,6</td>
<td>16,9</td>
</tr>
<tr>
<td>It is quite possible to have both a prosperous economy and a healthy environment</td>
<td>33,3</td>
<td>44,4</td>
<td>6,9</td>
<td>15,3</td>
</tr>
</tbody>
</table>
Learners (28.5% strongly agree & 29.2% agree) feel that they can personally help to reduce climate change by changing their behaviour while others (7.6% strongly agree & 16.7% agree) feel that there is not much they can do to reduce environmental problems.

Environmental practices

Graph 2 compares learners who feel can help the environment and who cannot change the environment.

The mean score is 15.2 with 51% of the ‘do not agree’ that they can help the environment.

Discussion

Findings of this study show that learners have limited knowledge on climate change, scoring a low mean of 3.9 (26%). Content coverage on climate change is very limited in the curriculum and this can be attributed to the relatively very low scores of students in this study. These findings concur with the findings of a study on Indian and Filipino primary and secondary school students which suggested that learners (Grade 4-6) showed little understanding of the concept of environmental education (Chapman & Sharma, 2006).

Knowledge is critical for one to be environmentally literate. From Tables 1 & 2 and Graphs 1 & 2 above, most of the learners exhibited little understanding of environmental issues and revealed many misconceptions about climate change issues. Few learners, using their scores on knowledge, would be categorised as functionally literate. Knowledge might inform how an individual may view and act on issues. Learners demonstrated average positive attitude towards the environment. These results demonstrate that these learners have great concern for the environment though they demonstrated little understanding of environmental issues, concurring with the Australian study (Esa, 2010).

Conclusion

Grade 9 Natural Sciences, Grade 10 & 11 physical Sciences learners at a school in Thokoza showed little knowledge of climate change. This might be partly due to limited content in their curriculum.
However, consistent with international literature, the learners showed positive attitudes and positive practices towards the environment, corresponding with the Brunei study (Esa, 2010).

References


CROSS FERTILIZATION OF IDEAS BETWEEN INDIGENOUS KNOWLEDGE AND WESTERN SCIENCE: The Complexity of Including Indigenous Knowledge in Science Lessons

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Abstract:
Cross fertilization of ideas between indigenous knowledge (IK) and western science (WS). This allow learners to use the knowledge gained at home in science classroom. This research followed the mixed method that allowed qualitative and quantitative data obtained from the learners. Data were obtained from lessons observed and group interview conducted with learners. Social constructivism was used as a theory and Dialogical Argumentation Instructional Model (DAIM) and Contiguity Argumentation Theory (CAT) as analytical tools.

Keywords: indigenous knowledge, indigenous language, cross fertilization of ideas, social constructivism, DAIM, and CAT.

Background

Learners find it difficult during science lessons when they are asked to relate their indigenous knowledge to western science, not only that they do not know that they might know it in their indigenous language and it difficult for them to translate it in the language of teaching and learning (LoTL). Some of the local terminologies are not yet in English language, even though some researchers argue that lack of indigenous terminologies hinders the inclusion of indigenous knowledge in science lessons. Indigenous language explicit not yet documented of which we argue that indigenous language is at it high level, and some of the local language is not yet in English language. Thus, this paper calls for cross fertilization of ideas from local language into English language or vice versa.

Literature Review

Dziva, Mpofu and Kusure (2011) posited that the difference between scientific and indigenous knowledge continue to create barrier to meaningful collaboration, as does the widespread assumption that science is superior to other knowledge systems. Learners always face the challenges to cross fertilize their indigenous knowledge (IK) into scientific or western knowledge (WS). Science teachers need to work with both world views as they complement each other and they are both superior in their own nature. Comparing indigenous knowledge world views and scientific knowledge
world view will expand the gap between them and learners will not be able to connect the two forms of knowledge. For non-western learners, interaction between two worldviews (IK and WS) characterizes much of their school experiences, complicating the learning process and potentially resulting in what Le Grange (2007) refer as cognitive conflict or dissonance.

This is the problem in Namibia, since IK is not documented; it is difficult for teachers to integrate it into their classrooms because they are not that knowledgeable about IK. Within South Africa, this has been further exacerbated by the lack of attention given by the national schooling curriculum to IK, the Curriculum 2005 (C2005), launched by the African National Congress (ANC), is primarily focused on Western-based scientific knowledge and gives very little acknowledgement to the fact that this knowledge is given in a cultural framework which is primarily based on indigenous epistemology (Cocks, Alexander & Dold, 2012). Cronje, de Beer and Ankiewicz (2015) highlight the following challenges:

- Science teachers struggle to incorporate indigenous knowledge into their lessons;
- Teachers were not exposed to the training on how to include IK since they were trained in so called “western science”;
- IK has a lack of instructional methods and pedagogical content knowledge;
- Science teachers fear that they will be teaching pseudoscience when integrating IK into western science;
- Indigenous knowledge has not been scientifically proven and it is not based on scientific methods; and
- Lack of literature or textbooks that include IK to be universal in all school in the country

Purpose and research questions

Cross fertilization of ideas is when the indigenous worldview and scientific worldview come together and co-exist. Aikenhead and Jegede, (1999) call such co-existence cultural border crossing. Cultural border crossing can serve science teachers who are regarded as pedagogical culture workers to make the culture of science accessible to all their learners (Jegede, 1999). It is acknowledged, however, that the complexity of indigenous language in science lessons hinder the inclusion of IK in science lessons. The aim of the study was thus to investigate the complexity of indigenous knowledge into science lessons that is taught in English when the teacher includes learners to give their IK during the science lessons. The study was guided by the following research questions:

- How do Grade 9 learners cross fertilize the IK into western knowledge during Physical Science lessons?
- What is the Grade 9 Physical Science learners’ indigenous knowledge practices on the topic of Acid and Bases?

Theoretical and analytical framework
Vygotsky’s (1978) social constructivist theory was used as the lens to analyse the data in this study. Social constructivism emphasizes the importance of culture and context in understanding what occurs as in society and constructing knowledge based on this understanding (Kim, 2001). Adding to this Kundi and Nawaz (2010), clarify that social constructivism puts focus on the collective learning, where the role of the teacher, parents, peers and other community members in helping learners becomes prominent. Additionally, the study employed the Dialogical Argumentation Instructional Model (DAIM) and Contiguity Argumentation Theory (CAT) as analytical tools to analyze the data obtained from the learners during science lessons. Ogunniyi and Hewson’s (2008) CAT has five cognitive categories to analyze the data. The dominant conceptions allowed the first author to observe how the learners used their dominant IK they gained at home in learning science concepts. Assimilated conceptions allowed learners to assimilate their IK with the western science and this could suppress the dominant conception. Emergent conceptions enabled learners without prior everyday knowledge to link the western science into the indigenous knowledge that they did not have at the beginning of the science lessons. Equipollent conceptions allowed learners with two worldviews to try and understand each world view. This is the point where we call its cross fertilization of ideas.

Research design and methods

This study adapted interpretive research paradigm approach with more focus on both qualitative data and quantitative. (Hussain, Elyas & Nasseef, 2013 and Cohen, Manion & Morrison, 2011), Interpretive paradigm seeks to understand values, beliefs and meanings of social phenomena of human social activities and experiences. This research collected data by using both qualitative and quantitative approaches. Mixed methods research also is an attempt to legitimate the use of multiple approaches in answering research questions, rather than restricting or constraining researchers’ choice (Johnson & Onwuegbuzie, 2004).

Sample

The study involved Grade 9 learners taught the topic on Acid and Bases in one rural school in Ohangwena region. The location of the school made it easy for us to make our study since most learners are not exposed to modern science. The class group was chosen based on the topic that was researched as the topic of acid and bases is more in Grade 9 curriculum. They were 26 learners in the class group and we only interview 12 learners. The group interview were tape recorded and transcribed.

Data collection and analysis

Data generated from the lessons observation and group interviews were analyzed by using DAIM and CAT. Lesson observation and group interviews data triangulated each other very well by making follow up from the lessons. The research followed mixed methods. DAIM allowed us to the dialogic between the learners and the teacher when IK was used as the teaching aid during the lessons and on how learners responded to the questions from the teacher. Learners supported their answer with
reasons and explanation during the lessons. We used Ogunniyi and Hewson (2008) Contiguity Argumentation Theory (CAT) five cognitive categories to analyze the data. The five cognitive categories helped us to work on the data by categorizing them based on the cognitive where they belong.

Trustworthiness and ethics

Before the research was conducted, as a researcher I have to adhere to the ethical consideration and I obtained consent of learners from the parents involved in the study. Cohen, et al., (2011) indicates that informed consent is the procedures in which individual choose whether to participate in an investigation after being informed of facts that would be likely to influence their decisions. Gay, Mills and Airasian (2011), qualitative researcher can establish the trustworthiness of their research by addressing the credibility, transferability, dependability, and conformability of their studies and findings as discussed below. Trustworthiness of the research depended on the triangulation of the data collected during the research.

Findings and discussions

The major findings of this study show that learners a loaded with indigenous knowledge before they enter science classroom and teachers need to use this knowledge to enhance the conceptual understanding of learners in science lessons. The study shows that using argumentation as a teaching model helped learners to reflect back and engage their indigenous knowledge in science lessons. Integrating IK into school science teaching is one way of maximizing the socio-cultural relevance of science education to enhance learners’ performance (Zinyeka, Onwu & Braun, 2016). However, some learners were not able to cross fertilize the indigenous knowledge into scientific knowledge.

Conclusion and Recommendations

Learners are knowledgeable about substances that has sour and bitter taste found at home or in the local environment. It emerges from this study that IK and WS could be taught simultaneously in science lessons not to discriminate IK over WS. We recommend that for the inclusion of IK to be fully implemented in science lessons, science teachers need to be trained on what aspect of indigenous knowledge need to be part of science lessons. The myth, cultural beliefs, indigenous knowledge, indigenous knowledge practices are all aspect of IK. To further recognize IK in science lessons, African university need to decolonize their science curriculum to trained new teachers before they enter the teaching market.

References


THEORISING ABOUT THE CONVERGENCE OF INDIGENOUS CULTURAL KNOWLEDGE AND TEACHING OF SEXUAL REPRODUCTION IN SOUTH AFRICAN HIGH SCHOOLS

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Abstract
The paper represents our first attempt to come to terms with the socio-cultural dynamics of teaching human reproduction by teachers of the same ethnicity as learners in South African high schools. We seek to increase understanding of how isiXhosa-speaking teachers teach sexual reproduction when the community where the learners come from does not talk publicly about sexual terminology. Specifically, our theorising attempts to explore prevailing cultural beliefs, attitudes, practices, values and language that teachers experience when teaching. The principal argument of this paper is; prevailing ways of how society views sexually-related biology content are socially produced. Based on reported cultural beliefs of Xhosa people, we structure the discussion around the dilemma of English as a language of teaching whilst biological terminology may not be available in the lexicon of the community.

Keywords: human reproduction; culture; collectivism; isiXhosa speaking; dysfunctional school

Introduction
This paper makes a tentative case that the number of dysfunctional schools, characterised by a ‘confluence of factors which depress learning’ are found mostly in rural areas (Maringe & Moletsane, 2015; p. 347). We believe that the Eastern Cape still bears footprints of marginalization, evident in statistical reports revealing a consistently poor national pass rate and poor school infrastructure (Chilisa, 2012; Province of the Eastern Cape, 2018). Thus, we chose sexual reproduction content based on the belief that there are accepted, non-written isiXhosa cultural beliefs and practices that prohibit the use of sexually-related terminology at school.

Literature

Human reproduction content in Life Sciences’ curriculum
Human reproduction consists mainly of the structure of the male and female sexual reproductive organs, carrying 57 marks out of 150 examinable questions in Paper 1, Grade 12 external examinations (South Africa, DBE, 2017). The point raised is not merely a challenge directed at naming of sexual parts but delves deeper by trying to find aggravating issues in literature pertaining to how teachers use anatomically correct terms (Buni, 2013; Doidge & Lelliott, 2016; Levinson, 2006) when teaching sensitive biological content. While we refute the use of euphemisms and colloquialisms
(Buni, 2013; Doidge & Lelliott, 2016), nevertheless we argue that science teachers are facing the “three-language” problem (Webb, 2009, p. 331) which makes instruction difficult. We suggest that biological terminology must be linked to the casual, home language drawn from a learner’s familiar culture. In so doing, culture can be used as a bridge that teachers can use to transcend into the language of instruction and science content (Webb, 2009).

**Role of culture and language**

Our definition of culture is positioned on studies emphasising the consideration of different cultural characteristics, values and contributions of different ethnic groups (Gay, 2002; 2010). We contend that culture is a ‘collective phenomenon’ (Triandis, 2018; p.4) and is linked to language and time. It is well-known from an early stage that a traditional Xhosa married male is prohibited from seeing his wife after childbirth due to traditional taboos associated with menstruation. Given this background, we agree with literature (Hofstede, Hofstede & Minkov, 2010) that teachers should note that societal, national and gender cultures that learners acquire from childhood are deeply embedded in the human mind, more so than occupational cultures learnt at school.

Missing Xhosa vocabulary about human reproduction organs is quite challenging. For example, the online English-isiXhosa dictionary does not have specific isiXhosa words, not even colloquial terms which can serve as labels of the different parts of the female reproductive system, except for the uterus. In isiXhosa, uterus is ‘isibeleko’ and there is no different term for the other parts of the female reproductive system, creating ambiguity. Grade 12 assessment requires learners to know the different parts and functioning of the female reproductive system such as (Isaac, Chetty, Naidoo, Manganye, Mpondwana, & White; 2013):

- two ovaries, producing ova
- menstruation, bleeding due to peeling of uterine lining
- uterus, site of menstruation and implantation of embryo.

A question arises as to how teachers teach sexual content when there is no lexicon in the learner’s home language.

**Conclusion**

The integration of culture with sensitive biology topics remains central to improving the teaching skills of isiXhosa speaking teachers working in dysfunctional, rural schools. We propose that teachers and researchers must devise gestures that can be used as cultural-relevant strategies before introducing standard, academic language.

**References**


PHYSICAL SCIENCE STUDENT TEACHERS’ VIEWS ABOUT BEING MENTORED, A LEARNING EXPERIENCE
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Abstract
The new Curriculum and Assessment Policy Statement (CAPS) has been implemented in all grades in South African schools since the beginning of 2014. The implementation of CAPS sees a shift from the previous outcomes-driven curriculum policy and prescribes to the teacher exactly what should be taught within specified timeframes for teaching and learning. This policy replaces the more open-ended outcomes-based policy. Practical work is an integral part of the new Physical Science curriculum policy. It embraces demonstrations, experiments or practical work and scientific investigations and is emphasised in both the current and new curriculum policies. Policy dedicates that learners engage in practical work for formal and informal assessment. The purpose of practical work is to strengthen the concepts being taught by integrating the theory and practical work (Department of Basic Education (DoBE), 2011). This study focuses on the assessment of practical work from a pre-service teachers’ perspective.

Practical work is essential in science teaching as it allows learners to work as scientists and engage in the processes of science. ‘Doing science’ or ‘hands on’ practical work is also stated as an aim of the new policy. The new policy document requires that practical work be assessed as part of the formal assessment of the learner or as part of continuous assessment. Considering the importance of assessment of practical work, this study allows the voice of pre-service teachers to be heard on the assessment of practical work. This study allows their voices to be heard through their personal reflections during teaching practice. With this in mind, this research aims to answer the following questions:

1. What are the policy requirements for the assessment of practical work?
2. What views do pre-service teachers have about the assessment of practical work?

This study was conducted in the Capricorn District of the Limpopo province of South Africa and is a follow-up to a previous study that was conducted with Bachelor of Education (BEd) students in 2014. Thirty-six (36) pre-service teachers participated in this study. The pre-service teachers are currently registered for a Post Graduate Certificate in Education (PGCE) which is an initial teacher education qualification. This is a one-year full time course for graduate science students who are specialising in the teaching of Physical Science. The researcher lectures Method of Physical Science in the
programme. Qualitative methods of data collection were used in this study. The data was collected through questionnaires, group discussions and document analysis.

An analysis of the policy document reveals that seven (7) formal practical assessments are required in the Further Education and Training (FET) Phase for Physical Science. Practical work can also be conducted for informal assessments. The number of formal assessments for practical work can be increased if learners undertake a practical investigation as a project. The policy also stipulates the experiments that learners need to do for formal assessment. This leaves little or no room for learners to engage in scientific investigation or scientific inquiry. Rubrics, checklists, observation schedules and memorandums are suggested assessment tools to be used to assess learners’ practical work (DoBE, 2011). The assessment tools imply that the assessment of practical work can be both written and oral, that is, while the experiment is conducted. Group discussions with pre-service teachers and analysis of questionnaires revealed that: pre-service teachers feel that the purpose for assessment of practical work must be made more explicit. Most pre-service teachers were of the view that practical work should be assessed by the teacher using a rubric to evaluate a learners’ practical report. They also held a contradictory view that a practical report is not evidence that the experiment was conducted by the learner. Other findings include, pre-service teachers felt strongly that assessment of practical work should also occur while learners engage in the experiment as their conceptual understanding can be probed by the assessor (teacher).

Pre-service teachers expressed their concern that the assessment of practical work is not uniform across all schools. They cited the lack of resources, laboratories and qualified teachers as some reasons for their concerns. They maintained that in most rural schools the assessment of science process skills cannot be assessed as learners are not involved in the ‘doing of science’ as per policy requirement. Learners in rural schools are disadvantaged during the assessment of practical work as they are assessed predominantly on written practical reports only. The practical reports are based on what they are ‘told’ or on a demonstration by the teacher. Pre-service teachers were of the view that the lack of basic infrastructure such as laboratories in rural schools will result in the formal assessments of learners being skewed towards written assessments only. This is contradictory to the policy requirements.

They further stated that practical work should be more open-ended rather than prescriptive as per the policy. They expressed concern that the new policy does not allow for any open scientific investigations. Pre-service teachers questioned written practical tests and were sceptical about them. They recommended that practical work be context specific and that teachers in a particular area be allowed to determine their own practical tasks. The final recommendation was that teachers must allow learners to must have a ‘voice’ in the assessment of practical work.

REFERENCES


EXPLORING THE CHALLENGES OF EVERYDAY ENGLISH WORDS IN LEARNING PHYSICAL SCIENCES IN GAUTENG EAST DISTRICT TOWNSHIP SECONDARY SCHOOLS

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Abstract
The study on Exploring challenges of everyday English language words in learning Physical Sciences in Gauteng-East Townships Secondary schools highlights the difficulties learners encounter in learning and developing scientific concepts and vocabulary. This study was conducted in four township secondary schools. A questionnaire consisting of 25-item multiple choice items and a semi-structured interview provided data for this study. Data collected were analysed both quantitatively using tables, graphs, statistical techniques and qualitatively using interviews. An overall percentage mean scores of correct responses in the questionnaire for schools W, X, Y and Z was 47.2%, 56.9%, 55.2% and 57.2% respectively, indicated that participants in the study have limited knowledge of everyday English words when used in a science context. There was no significant gender discrepancy noted in the performance. In-depth analysis of the results revealed that the underlying difficulties were as a result participants’ relative levels of proficiency in English language, lack of precision in use of this language, misreading, and confusion in the use of words. Furthermore, the results were consistent with earlier findings from other countries as reported by various authors. It is envisaged that the findings will contribute to effective classroom instruction and teacher education from the perspective of language in science. This paper will only report on findings of the questionnaire analysis.

Key Terms: First Additional Language (FAL), Second Language, Physical Sciences, Language of Learning Teaching (LOTL).

Introduction

Minchenton and Exley (2009) are of the view that much of the research into school science focuses on scientific content, often ignoring the literacies that carry and connect the content. The impact of the science classroom language on learners in science education has been explored in South Africa. Findings have been made on areas such as language proficiency and the place of indigenous languages in science education, language misconceptions as a confounding factor to learning science, language code switching to enhance learning and understand science content. However scant studies in South Africa have reported on learners’ difficulties with meanings of everyday words when used in a science context. Oyoo and Semeon (2015) points out that the lull in global research in the area of language of instruction in science education perhaps explains the absence of recent published studies focusing on student difficulties with everyday words of the science classroom language.
Authors and researchers internationally have published studies focusing on student difficulties with everyday words of the science classroom language in different grades and language backgrounds.

Setati (2011) states that many words have specific meanings in science that is different from the meaning of the word as used in everyday contexts. In a science classroom, the correct use of words is of paramount importance in understanding the meanings of science concepts and knowledge. It is from this view that the language used in science classroom must carry the necessary vocabulary for providing a choice of appropriate words that can be utilised. This paper has drawn from secondary schools in the townships in the Gauteng east district where learners are from a unique social background and are taught in a second language. It is thus difficult to speculate on specific causes in that context.

However, based on the background of research work done in this area, the problem merits further investigation.

Literature review

According to Tank & Coffino (2014), participating and expressing science understanding through talk is an integral part of communicating the knowing and doing science. Science classrooms are generally associated with a plethora of learning activities such as skills learning for practical work, projects to model science including communicating science concepts. One of the challenges encountered are the use of words employed by a language in communicating science phenomenon. According to Farrell and Ventura (2010) there is a body of research that suggests that word understanding can have a direct bearing on attainment in science education. Furthermore, Cohen (2012) states that without command of the meaning of the words, the underlying concepts they label will never fully be mastered. Thus, the goal of every science classroom is to assist learners to develop the desire to learn the meanings of words and understand their use in a science context.

Theoretical Framework

The challenges in understanding the meaning of words in learning Physical Sciences in the context of classroom activities is a possible explanation for the source of difficulty in the language of instruction. This study is informed by one of the five hypotheses of Krashen’s Monitor Model namely, the Input Hypothesis. For Krashen, the Input Hypothesis holds a special place because the hypothesis attempts to answer the crucial question of how we acquire language (Zafar 2009). Furthermore, as Krashen (1985) further states, since second language learners acquire the use of language in a predictable natural order, it would be relatively easy if second language teachers could detect the level of competence of learners and device teaching materials accordingly (Zafar:2009). According to Setati (2011), the input hypothesis states that in order for language acquisition to take place, the acquirer must receive comprehensible input through reading or hearing language structures that slightly exceed their current ability. Thus, the recognition of the meanings of words in a language when used
in a particular context maybe regarded as key to excellence particularly in science learning and understanding.

**Research Design**

In this study the researcher used a survey as the overall research approach because information collected from a survey represent a broad picture of the population and can produce patterns when analysed. The survey included the questionnaire (quantitative). The questionnaire was deemed as the most appropriate data collection method for this study as it provided the basis for comparing and contrasting data collected.

**Sampling**

The sample of this study was conveniently selected from all Physical Sciences learners in their classrooms (N=138) doing grade 11 in each of the four schools. Learners in the sampling frame were 18 years and below. The criteria for selecting schools were based on the schools’ accessibility, availability and provision of Physical Sciences as a learning area.

**Data Analysis**

The questionnaire recorded maximum responses i.e. most participants provided responses in the questionnaire with the exception of few questions left unanswered. The questionnaire responses were analysed statistically using tables and graphs to obtain patterns and to arrive at conclusion in answering the research questions. The Automated Readability Index concept on readability of texts was used by the researcher to establish criterion for classifying words as difficult for a learner who is at a particular level of grade and age based on text comprehensibility. According to Chall & Dale (1995), Flesch Reading Ease for grade 12 English language literature is 56.6%. Based on these findings, the researcher assumed that a word was considered difficult for grade 11 township secondary schools’ learners whose age range from 17-19, if a score of below 60% was achieved in the questionnaire by participating learners.

**Results / Findings**

The overall performance by learners from schools W, X, Y and Z were separately represented graphically as shown in the graphs below. The highest or tallest bar in the learner performance graph indicates the highest percentage the learner has obtained in word understanding. It further indicates that if the highest or tallest bar in the learner performance graph is below 100%, none of the learners knew all the meanings of everyday words when used in a science context.

In school W (N=43) as shown in the graph below, the highest score of 80% (n=1) indicated that none of the learners understood all the meanings of everyday words when used in a science context. The
least score of 28% (n=1) indicated that all learners were familiar with some everyday words though their knowledge of using them in a science context varied and was limited.

A criterion of below 60% suggested that 30% (13/43) of learners in school W have a better understanding of the meaning of words in a science context. Therefore, the overall score 47.2% suggests that the majority of learners in school W have a challenge of understanding the meanings of everyday words when used in a science context.

In the graph below of school W, the 16 words emerged as difficult words for learners in school W because they were below a criteria of 60% correct responses.

The word device was considered the least difficult word on average with 53% of learners scoring correctly. The word valid was considered as the most difficult word on average with 12% of learners scoring correctly.

In school X (N=26) as shown in the graph below, the highest score of 80% (n=3) indicated that none of the learners understood all the meanings of everyday words when used in a science context. The least score of 32% (n=2) indicated that all learners were familiar with some everyday words though their knowledge of using them in a science context varied and was limited.
A criterion of below 60% in scores suggested that 46% (12/26) of learners in school X have a better understanding of the meaning of words in a science context. Therefore, the overall score 56.9% suggests that the majority of learners in school W have a challenge of understanding the meanings of everyday words when used in a science context.

In the graph below of school X, the 12 words emerged as difficult words for learners in school X because they were below a criteria of 60% correct responses. The word contaminated was considered the least difficult word on average with 58% of learners scoring correctly.

The word convention was considered as the most difficult word on average with 4% of learners scoring correctly.

In school Y (N=34) as shown in the graph below, the highest score of 92% (n=1) indicated that none of the learners understood all the meanings of everyday words when used in a science context. The least score of 24% (n=1) indicated that all learners were familiar with some everyday words though their knowledge of using them in a science context varied and was limited.
A criterion of below 60% suggested that 38% (13/34) of learners’ school Y have a better understanding of the meaning of words in a science context. Therefore, the overall score 55.2% suggests that the majority of learners in school W have a challenge of understanding the meanings of everyday words when used in a science context.

In the graph below of school Y, the 15 words emerged as difficult words for learners in school Y because they were below a criteria of 60% correct responses. The words negligible and Random were considered the least difficult words on average with 59% of learners scoring correctly. The word valid was considered as the most difficult word on average with 12% of learners scoring correctly.

In school Z (N=35) as shown in the graph below, the highest score of 88% (n=1) indicated that none of the learners understood all the meanings of everyday words when used in a science context. The least score of 32% (n=1) indicated that all learners were familiar with some everyday words though their knowledge of using them in a science context varied and was limited.

A criterion of below 60% achievement suggested that 43% (15/35) of learner’s school Z have a better understanding of the meaning of words in a science context. Therefore, the overall score 57.2%
suggests that the majority of learners in school W have a challenge of understanding the meanings of everyday words when used in a science context.

In the graph below of school Z, the 13 words indicated emerged as difficult words for learners in school Z because they were below a criterion of 60% correct responses. The word consistent was considered the least difficult word on average with 57% of learners scoring correctly. The word valid was considered as the most difficult word on average with 11% of learners scoring correctly.

Conclusion

The findings of the study, through quantitative data analysis (graphs), concluded that learners at township secondary schools experience challenges with regard to using everyday words in a science context. The challenges could be attributed to lack of precision with the use of the language, misreading of words, confusion with words with sound alike and varying levels of proficiency in the English language even though in this study the levels of proficiency were not assessed. Teacher language skills and pedagogical approach in instructional language does not provide substantial impact in the learning of science.
Tank, KM. & Coffino, K. 2014. Learning science through talking science in elementary classroom. University of Minnesota, Minneapolis, MN, USA.
Abstract

Electronic quizzes have the potential to address the poor science achievement of South African township learners by extending learning time and providing immediate feedback beyond teachers’ input. However, this potential can only be realised if such learners have a sufficiently autonomous orientation to motivation to self-direct their quiz engagement effectively. In this study I seek to deduce the level of autonomous orientation of various achievement groups of township learners from their electronic quiz engagement characteristics and, therefore, the likelihood of quiz engagement being a viable intervention strategy for improving these learners’ science achievement. Twenty-nine grade 8 learners from two township schools participated in this pragmatic, exploratory research which had two components: (1) A 7-week intervention period during which learners completed structured diaries as they engaged with electronic quizzes for an hour per week after school; (2) An observation session where each learner engaged with two quizzes, of different language demand, on a computer fitted with eye-tracking hardware and software, while a video was recorded of their eye movements and mouse-clicks. Data were analysed using descriptive statistics about time, scores and types of quizzes engaged in for three achievement groups of the learners. The findings suggest that lower and medium achieving township learners appear to exhibit introjected self-determination, engaging readily with very low-language-demand quizzes which can be completed quickly and which yield high feedback scores, while avoiding more challenging quizzes. When forced to engage in a quiz with a greater language demand, such learners tend to resort to button-pressing with little reading of the quiz text. In contrast, higher achieving township learners appear to be able to internalise learning goals to a considerable extent and so choose to engage in more difficult quizzes for longer, suggesting that electronic quiz engagement may be a viable strategy for promoting science performance among such learners.

Introduction

Extension of learning time and provision of immediate, individualised feedback (Todd & Mason, 2005), both strengths of electronic quizzes, are known to enhance learning effectiveness. In the South African township context, where learning time is severely reduced by dysfunctionality (Van der Berg, Spaull, Wills, Gustafsson, & Kotzé, 2016), and large class sizes make provision of timely feedback difficult, extension of learning time and provision of feedback are particularly needed if we are to improve learners’ science achievement from its current state, where it ranks amongst the worst in
According to Ryan and Deci’s (2000) Organismic Integration Theory (OIT) there are four regulatory styles possible within extrinsic motivation, depending on the degree to which the learner has internalised and integrated the goals of the activity and is therefore able to self-regulate their engagement. The drivers of these styles are: Rewards and punishments provided by an external source for external regulation; The ego as the learner seeks to win the approval of self and others for introjected regulation; Self-regulation resulting from the learner having made the learning goals their own for identification and integration. External and introjected regulation styles are viewed as control-, whereas internalised, integrated and intrinsic regulation styles are viewed as autonomous-orientations to motivation. Engaging in an activity, such as an electronic quiz, provides a learner with feedback which may challenge their self-concept. According to OIT, learners with a more autonomously oriented motivation are less likely to respond to such experiences defensively, such as through avoidance of the challenging activity, since an autonomous orientation is associated with a more resilient self-concept (Hodgins, Yacko, & Gottlieb, 2006).

Problem statement

This leads to the following question: Do South African township learners display a sufficiently autonomous orientation to motivation to be able to benefit from voluntary after-school engagement with electronic quizzes for learning science? In this study I attempt to deduce motivation type from the learners’ engagement choices made in two contexts: their self-directed electronic quiz engagement during a 7-week intervention period and during a researcher-observed, stipulated, engagement with two quizzes of differing language demand. The research is focused by the questions: (1) How did the choices learners made regarding the numbers and types of quizzes to engage with, and the times spent engaging with the quizzes, differ between achievement groups during the intervention period? (2) What do the learners’ scores and quiz-completion times for a lower- and higher- language-demand quiz, engaged in under observation, reveal about engagement differences between achievement groups?

Method

This is a mixed method case study guided by Plowright’s (2011) pragmatic Framework for Integrated Methodology (FraIM).

The sample

The 29 grade 8 learners from whom data were collected in this study were identified by their teachers as being higher achievers in two township schools in Botshabelo. These learners engaged in a 7-week intervention about electric circuits, including one hour per week during which the learners engaged with electronic quizzes, the structures of which they were familiar with from previous interventions,
after school time in the school’s computer classroom. This involved 30 learners having access to 20 school laptops at School 1 and 25 learners having access to 7 school laptops at School 2. Generally, the learners were left unattended in the computer classroom during these periods. The 29 grade 8 learners who submitted the structured engagement diaries at the end of the intervention period form the sample of this study. The marks these learners achieved in a Natural Sciences test after the intervention period ranged from 11% to 93%, with an average of 53%, suggesting a varied, but relatively strong, sample.

**Data collection**

First, self-report data were collected from the 29 learners during the 7-week intervention period in the form of structured engagement diaries. Additionally, acting as both teacher and researcher during this intervention, I wrote daily field notes about my observations pertaining to the learners’ engagement in the teaching sessions of the intervention, which occurred for an hour either before or after the quiz-engagement session. Further, groups of learners participated in focus-group discussions in a loosely-structured, exploratory manner, on 8 occasions during and after the intervention period, and the voluntary notebooks the learners used throughout the intervention period were perused and notes made about observations.

Second, 28 of these 29 learners engaged with two electronic quizzes on a Tobii TX300 eye-tracker fitted with Tobii Studio 3.4.5 eye-tracking software. A screen-capture video was taken as each of the learners engaged with a gap-fill and multiple-choice quiz. This video included a red dot indicating the learner’s gaze. The gap-fill quiz was modified from a quiz the learners had previously engaged in and only required selection of either more or less from a drop-down list for each of 7 options to complete notes on adding resistors in parallel. The multiple-choice quiz had 4 multiple-choice questions, each with 4 options, and was based on a text about lightning. This was completely unfamiliar to the learners.

The following data were extracted from the eye-tracking video: The time the learner took to complete each quiz and the scores the learners obtained on pressing the submit button on their first attempt for the gap-fill quiz. Additionally, the video was used to derive a score for each learner for the multiple-choice quiz as follows. If a learner’s eye movements showed that an option was chosen without the learner having read the question or the option, the learner was assigned 0% for that question. Otherwise, a correct answer was awarded 100% if obtained on the first attempt, with 25% deducted for each additional attempt.

The two data collection periods occurred a little over a year apart from one another for pragmatic reasons, namely as I analysed the self-report data from the first data collection period, I became aware of the need to observe the learners’ engagement with various levels of difficulty of quizzes individually, and was only able to gain access to an eye-tracker to do so a year on.

*The achievement categories*
Learner performance on a common test written at the end of the intervention period was used to form three achievement categories (see Table 1). These ranges were found, through an iterative process of data analysis, to best group learners into similar types of engagement. The learners also wrote pre- and post- tests at the start and end, respectively, of the intervention period. These tests were identical to one another and are discussed in detail in Stott (2017). As shown in Table 1, all three groups achieved similar low pre-test averages with the lowest achievement group, surprisingly, scoring the highest of the three. Post-test score averages were, however, markedly different between the three groups and correspond to the common test achievement trends, as do pre-post test improvement scores. Therefore, the three achievement groups can be seen to differ in the extent to which the learners underwent the kind of learning required for successful performance on science tests, referred to here as effective learning. The learning that occurred between the pre- and post-tests was not restricted to engagement with the quizzes, including normal lessons for the learners in School 2, although not in School 1 since no teacher was present during this period. Additionally, I taught the learners for one hour a week for the 7-week intervention period. Further, at least some of the learners engaged with the work at home.

Table 4 Characteristics of the three achievement categories

<table>
<thead>
<tr>
<th>Common test range</th>
<th>Common test (%): M (SD)</th>
<th>n (self-report data)</th>
<th>n (observation data)</th>
<th>Pre-test score (%): M (SD)</th>
<th>Post-test score (%): M (SD)</th>
<th>Pre-Post-improvement (%): M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;59%</td>
<td>72 (10)</td>
<td>9</td>
<td>9</td>
<td>34 (14)</td>
<td>56 (17)</td>
<td>23 (20)</td>
</tr>
<tr>
<td>46%-59%</td>
<td>53 (4)</td>
<td>10</td>
<td>10</td>
<td>31 (8)</td>
<td>46 (13)</td>
<td>16 (14)</td>
</tr>
<tr>
<td>&lt;46%</td>
<td>39 (9)</td>
<td>10</td>
<td>9</td>
<td>37 (12)</td>
<td>37 (12)</td>
<td>-1 (12)</td>
</tr>
</tbody>
</table>

Data analysis
Descriptive statistics were used to analyse the quantitative data and the data were graphed in a variety of ways in a pragmatic search for answers to the research questions. Summaries made of each of the audio-recorded focus-group sessions, the field notes and reports about the learners’ note books, were searched for confirming and disconfirming evidence relative to the findings which emerged from analysis of the quantitative data.

Results

Engagement choices during the intervention period
The learners had approximately 7 hours (420 minutes) to engage with the quizzes, roughly a quarter to a third of which the learners of the highest achieving group reported actually engaging with the quizzes, with the middle and lowest achievement group learners reporting doing so for roughly an eighth and a sixth of the time, respectively (see Table 2). Particularly for School 2, where only 7 laptops were available for 25 learners, some of this time was spent waiting for a chance to have access to the computer. The lower total engagement for the middle achievement group can probably be ascribed to this group being comprised of a higher proportion of learners from School 2 than for
the other two groups. Therefore, comparisons of total times and numbers of quizzes engaged with between the middle achievement group and the other groups are not meaningful for understanding differences in motivation. From the focus-group discussions and from perusal of the learners’ books, it is clear that the learners at least some of the time available to discuss the quizzes with their peers and to copy down notes.

As shown in Table 2, the learners in the highest achievement category engaged with more quizzes and spent nearly double as much time engaging with the quizzes, on average, and engaged with roughly double as many gap-fill and multiple choice quizzes, on average, than the lower-achieving learners did. The gap-fill and multiple-choice quizzes have a higher language demand than the match quizzes, which probably contributes to the lower average score per quiz and longer times for completion recorded for the highest achievement category. Other probable reasons for this finding are that the higher-achieving learners chose to engage with the more cognitively challenging of the gap-fill quizzes than the other learners did. Qualitative evidence for this claim includes the observation, recorded in the researcher field notes on 01/09, that these learners were correctly able to predict the counterintuitive effect of adding resistors in parallel on bulb brightness on first exposure to this concept. In focus-group discussions on 14/09 and 5/11, these learners ascribed this ability to having completed the gap-fill quiz about this topic before being taught the topic. These learners meticulously copied the completed gap-fill quizzes into their exercise books and reviewed them at home.

The data for the middle and lowest achievement groups appear similar in high average score and short average time spent per quiz, suggesting that these learners chose to engage with the easier quizzes. On 3/11 I attempted a focus-group discussion with the learners of the lowest achievement category. However, their poor English ability made it impossible to make much progress with the discussion which mainly consisted of them agreeing with whatever I said. Given that English is the language of learning and teaching (LOLT) and that all these quizzes are in English, this finding is consistent with the deduction that these learners chose to engage with the easier and lower-language demand quizzes.

Table 5 Quiz engagement statistics for the 7-week intervention period according to self-report data

<table>
<thead>
<tr>
<th>Common test range</th>
<th>n for each school</th>
<th>Average number of quizzes recorded: M (SD)</th>
<th>Average quiz score (%): M (SD)</th>
<th>Average time spent per quiz (min): M (SD)</th>
<th>Average total time spent engaging with quizzes (min): M (SD)</th>
<th>Average number of quizzes per learner (where this information was provided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;59%</td>
<td>7</td>
<td>18,6 (8,1)</td>
<td>82 (10,4)</td>
<td>6,4 (4,0)</td>
<td>119 (88,1)</td>
<td>4,1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2,6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10,2</td>
</tr>
<tr>
<td>46%-59%</td>
<td>3</td>
<td>9,7 (6,2)</td>
<td>87 (7,8)</td>
<td>5,3 (5,5)</td>
<td>51,9 (51,4)</td>
<td>1,9</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4,2</td>
</tr>
<tr>
<td>&lt;46%</td>
<td>3</td>
<td>12,7 (4,4)</td>
<td>85 (7,8)</td>
<td>5,5 (2,9)</td>
<td>69,9 (42,4)</td>
<td>4,4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4,9</td>
</tr>
</tbody>
</table>
Performance for two observed quizzes

As shown in Table 3 and Figures 1 and 2, when engaging in the two observed quizzes, the three achievement groups differed relatively little regarding their engagement times and scores for the lower-language-demand gap-fill quiz, but differed markedly with regards to these variables when engaging with the higher-language-demand multiple choice quiz where the learners in the highest achievement group scored nearly double as high, on average, as the middle group, which achieved more than double as high, on average, as the lowest performing group. The learners in the lowest achievement group displayed a high degree of guessing, as deduced from their eye-movements, as previously described, and as indicated by very low scores, in many cases zero (see Figure 2). Two of the learners in the lowest achieving group gave up before completion of the higher-language demand quiz, and therefore had to be excluded from the data set with regards to time. Both of these guessed the questions which they did attempt (1 and 3 questions respectively), thus each earning a zero score. Some of the learners who only resorted to guessing to answer this quiz took a long time to complete the quiz, resulting in this group’s average time spent on the quiz being the longest of the three.

Table 6 Quiz engagement statistics for the researcher-observed quizzes

<table>
<thead>
<tr>
<th>Common test range</th>
<th>Lower-language demand gap-fill quiz</th>
<th></th>
<th>Higher-language demand multiple choice quiz</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Average score (%) : M(SD)</td>
<td>Average time for completion (min) : M (SD)</td>
<td>n</td>
</tr>
<tr>
<td>&gt;59%</td>
<td>8*</td>
<td>72,8 (15,2)</td>
<td>1,5 (0,7)</td>
<td>9</td>
</tr>
<tr>
<td>46%-59%</td>
<td>9</td>
<td>64,6 (18,0)</td>
<td>1,6 (0,7)</td>
<td>10</td>
</tr>
<tr>
<td>&lt;46%</td>
<td>9</td>
<td>62,9 (24,3)</td>
<td>1,9 (0,5)</td>
<td>9(7)**</td>
</tr>
</tbody>
</table>

*The data for one of the learners in this group had to be excluded for technical reasons.

**Two learners exited the quiz before completion. They are included in the score, but not time, data set.

In general, higher achievement on the lower-language-demand quiz was associated with a shorter time to completion (see Figure 1) while higher achievement on the higher-language-demand quiz was associated with longer time to completion (see Figure 2). This trend is consistent with the deduction, made from the self-report data, that the lower- and middle-achieving groups’ relatively low average times and high average scores suggest engagement with the easier quizzes at the expense of the more difficult quizzes.
Discussion

The impression, gained from the self-report data, that the lowest- and middle- achievement group avoided the more difficult and higher-language-demand quizzes in favour of engagement in easier quizzes which they engaged with quickly and for which they achieved high scores is consistent with the prevalence of reading avoidance and guessing for the higher-language-demand observed quiz amongst these learners, particularly among the lower achieving learners. These findings suggest that these learners were driven by an introjected extrinsic motivation, relying on gratification of the ego rather than on internalisation of the goals of the activity (Ryan & Deci, 2000) and, consistent with this, displaying defensive behaviour (Hodgins et al., 2006) through avoidance and attempts to game the system. This was particularly the case for the lowest achieving learners. Further, these learners’
low pre-post-score gains and poor achievement in the common test suggest that the activities they engaged in throughout the 7 week-intervention period, including their engagement with the quizzes, did not result in much effective learning occurring with respect to what is measured in grade 8 natural sciences tests. This does not mean that no learning occurred, however. Nor does it necessarily mean that had these learners been encouraged or forced to engage in more difficult quizzes that they would have achieved higher on the tests.

In contrast, the learners in the highest achieving group chose to engage in more difficult quizzes, even on topics they had not yet been taught about, copying the completed quizzes down in their notebooks and reviewing this text at home, thus further extending their learning time. They were prepared to do this even though this meant that they had to spend longer and achieve lower scores, per quiz, than if they had only chosen out the easier quizzes to answer, possibly multiple times. This behaviour is consistent with an autonomous motivation orientation guided by an identified regulatory style resulting from an internalisation of the goals of the activity (Ryan & Deci, 2000).

These findings are consistent with those made by Lidbury and Zhang (2008), who studied English foreign language molecular biology university students’ engagement with quizzes created with the same HotPotatoes freeware as used in this study. Although all the students in their study attributed a feeling of enhanced language efficacy to the quiz engagement, evidence for improvement in marks associated with quiz engagement could only be shown for the higher achieving students.

Conclusion

When one teaches learners, who have ubiquitous access to ICTs, one occasionally feels frustrated by the learners’ lack of autonomous motivation to use those ICTs to enhance their learning of science. At least for the highest achievement group of learners described in this research, the opposite frustration presents itself: although these learners are autonomously motivated to make use of ICTs to enhance their learning of science, they are generally prevented from doing so by a lack of access to ICTs. This research suggests that it is worthwhile investing in provision of the necessary access in a targeted manner to higher achieving South African township learners since they do seem able to self-direct their use of educational software, such as electronic quizzes, autonomously, displaying identification regulation.

References


Van der Berg, S., Spaull, N., Wills, G., Gustafsson, M., & Kotzé, J. (2016). Identifying Binding Constraints in Education. Stellenbosch: Department of Economics, University of Stellenbosch
DEVELOPING STRATEGIES FOR TEACHING CRITICAL THINKING IN PHYSICAL SCIENCES AT SELECTED SCHOOLS IN MASHISHILA CIRCUIT IN MPUMALANGA PROVINCE

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Background

One of the goals of science education is to develop the following life skills in student: the ability to adapt to different conditions, flexibility in thinking, having a curious mind, being creative, exercising of critical and analytical skills, having respect for people around them and the tolerance of ideas and opinions that are different from theirs. (Aktamis & Yenice, 2010). In the 21st century, critical thinking has been found to be one of the essential skills that learners must possess (Prayogi, et.al. 2018). It helps the learners to survive in the world of work where they are expected to process and analyze information so that they could make wise decisions. Critical thinking is usually taken as the individual’s mental skills such as verifying a knowledge using various criteria as one decides on a subject, and trying to provide evidence on what has read or heard before accepting the idea (Ozdemir, 2005).

In South Africa, there has been a concern about the quality of education at the high school level. South African Institute of Physics (SAIP) (2013) revealed that poor quality education, especially in Mathematics and Physical Science at high school resulted in the poor quality of students entering institutions of higher learning). The Physics community cited that students leaving high school lacked preparedness especially in Mathematics and problem-solving skills. From the progress report by the National Education Evaluation Development Unit (NEEDU 2013), the lack of student preparedness was blamed on the teachers’ who did not have requisite content and pedagogical knowledge. This shows that there is need for teachers to assist these students to conceptualize or think critically. This research was carried out in the Mashishila circuit in the Mpumalanga province.

Purpose of the Study

This study looks at the Physical Science teachers’ understanding of the concept of critical thinking and the strategies they employ in their teaching of the subject in order to assist learners to develop critical thinking. The following questions guided the study:

1. How do teachers understand the term ‘critical thinking’?
2. Which strategies do teachers use in order to assist Grade 10 learners to develop teaching critical thinking in Physical Science?

Literature review

Theoretical Framework
This research has been anchored on the model of Pedagogic Content Knowledge (PCK). The PCK concept was defined by Shulman (1986) as the teacher’s interpretation and transformation of subject matter knowledge in facilitating student learning. Of the key elements of the PCK, the study will concentrate on the teaching strategies for the promotion of critical thinking.

Critical Thinking
There is a wide acceptance of the idea that critical thinking should be an important dimension of science education, Bailin (2002). One of the cornerstones peculiar to the outcome-based approach adopted by the South African Education and Training sector is the so called ‘critical outcomes’ of which the ability to think critically is one of the outcomes, Lombard (2008).

Paul and Inhelder (2007) describe critical thinking as an art of analyzing and evaluating thinking with a view to improve it. A similar thought describes it as a process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/ or evaluating information gathered from or generated by observation, experience, reflection, reasoning, or communication as a guide to belief or action, (Scriven and Paul, 2008 and Lipman, 1987). There are two general characteristics that can be deduced from these definitions: critical thinking is self-corrective, and it is thinking that is based on some standards.

For thinking to be self-corrective, it has to be subjected to self-criticism where one questions a lot before coming to some acceptance of a thought or an action. This would then have implications to the classroom where the learners would be questioning during their discussion or during inquiry activities. The learners will be seeking answers, looking for evidence and drawing up conclusions from given data. However, this process of critical thinking can only take place based on certain standards which are presented in the next section

Standards
From the discussions above, the development of critical thinking involves skills and dispositions which can be improved. A skill is a performance that can be measured against a certain yardstick or standard. For one to make a judgement of an assertion, one needs a measure or standard of judgement, and to classify, one needs categories for classification. This leads us to look at what leading authors have said about the standards for critical thinking skills.

Lipman (1988, 1991) listed criteria for judgement of which values, standards, definitions and rules form part. A list of standards that have been provided by a number of the authors include: clarity,
accuracy, precision, relevance, depth, breath and logic, (Paul and Elder 2007, Ennis 1985) These standards can easily be put into use for the development of critical thinking through suitable strategies for the South African Physical Science learners.

Methodology

A qualitative approach was used for the collection of data. 12 teachers teaching Grade 10 Physical Science in 10 schools in the Mashishila circuit participated in the study. Purposive sampling was used to select Mashishila circuit from the Mpumalanga province. All the Physical Science teachers teaching Grade 10 in the circuit were involved in the study. Data were collected through self-administered open-ended questionnaire which was completed by all the participants in the schools that the researcher visited. The researcher waited to collect the completed questionnaires to ascertain a 100% return. The open ended questionnaire sought to reveal the period the teachers had taught Grade 10; what they understood by the term ‘critical thinking’, as well as the strategies and methods they used to teach critical thinking.

Data were analyzed using content analysis concurrently with data collection. The open-ended questionnaire from all the participants was transcribed on the same day the data were collected.

Findings

a) What do you understand by Critical thinking?

The three categories which emerged were as follows:

i. Solution to problems: the participants defined critical thinking as, ‘to think broadly about a given phenomenon’, ‘being able to reason and apply your thinking on finding solutions to problems’ or ‘a major way of how you see a problem and thinking of a viable way needed to solve it’ were given. They also said it was a way ‘to apply facts to solve a problem’.

ii. As a Skill: Participants indicated that critical thinking was that mode of thinking that improves thinking by skillfully analyzing, assessing and reconstructing a problem or any subject content., a thinking in depth which promotes understanding through analysis and evaluation.

iii. As Creativity The participants explained it as: ‘thinking on your own self to create something’ The emphasis of the participants highlighted independent thinking of an individual to come up with something new.

b) What strategies do you use to teach Physical Science?

The participants identified the strategies for teaching critical thinking: use of group work, media, experimental activities, practical investigation, problem solving and written work.

c) What methods would you use to teach critical thinking?
Participants listed the methods as: the use of group work, use of media, practical investigation, use of question and answer, lecture methods and demonstration. They also suggested weekly or monthly tests to assess and evaluate the learners’ understanding of taught concepts.

Discussion

The definition of critical thinking which was given by the participants was similar to that given by Costa & Kallick (2009). The participants defined critical thinking as the ability to reason and apply one’s thinking, which Costa & Kallick referred to as the improvement and application of interrelated cognitive and meta-cognitive skills, on finding solutions to problems. The skills the teachers gave as the definition of critical thinking were described by Facione (2015) as cognitive skills which according to Facione were at helm of critical thinking. These cognitive skills include: interpreting, analyzing, evaluating and making inference. The only confusion that some of the teachers brought was equating critical thinking to creative thinking, yet these are two different concepts.

From the study findings, the concept of strategies and methods seemed to be synonymous where for example questioning can fall either under strategies or methods depending on the context.

Conclusion

Participants described critical thinking as ways of thinking deeply in order to promote analyzing, assessing and applying facts to solve problems. Strategies given were use of group work, media, experimental activities, practical investigation, problem solving and written work.

References


EFFECTS OF DIALOGICAL ARGUMENTATION ON MIDDLE SCHOOL STUDENTS’ EPISTEMIC KNOWLEDGE: A Preliminary Analysis of Physics Reasoning Test

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Abstract
The aim of the study is to investigate the effect of dialogical argumentation on middle school students’ epistemic knowledge on the basis of the pre-test and post-test of the physics reasoning test. It is important to note that this is preliminary analysis. Nevertheless, it is an attempt to highlight how and in what ways engagement in dialogical argumentation affect middle school students’ epistemic knowledge. The methodology followed in this research is quasi- experimental research design. The research analysed at the nuances of epistemic differences between treatment and control group through physics reasoning test. Winsteps 3.68 were used to analyse the data. The finding showed that there is a significant difference between the pre- test and post-test score for the intervention group while no significant difference is observed between the pre-test and post-test score for the control group. However, the level of epistemic knowledge of the intervention is still below the average score of the physics reasoning test. The analysis shows that middle school students have a poor epistemology of science.

Key Word: dialogical argumentation, physics education, epistemic knowledge

Introduction
In the past three decades, physics education research revealed students’ difficulties in learning physics concepts. The learning difficulties mainly arise from student’s misconceptions, gap in scientific knowledge and skills, and approach to learning and understanding physics (Driver, Newton, & Osborne, 2000). To deal with these difficulties, physics education needs an effective pedagogy. Recently, dialogical argumentation had emerged as a means to bring the practice of science to the classroom, and by doing so develop the scientific knowledge of students and make them scientifically literate. However, existing research do not address all elements of scientific knowledge and little attention is given to the epistemic knowledge (EK) of science. In addition, previous studies fail to consider the features of EK elicited during dialogical argumentation.

This research seeks to investigate how engagement in dialogical argumentation influences the EK and to identify features of EK observed. Here, I argued that the development of scientific knowledge in science has been dwarfed by too much attention to the elements of content knowledge that are exclusionary of entities of epistemic and procedural knowledge. Science education researchers
suggest that EK of science have been overlooked and sometimes depicted differently in the discourse of argumentation in science education (Sandoval, 2005). As such, this paper responds to the call of inculcating the epistemic understanding by many science education scholars. EK of science is one of the distinguishable elements of scientific knowledge that has been identified as a key objective of science education to introduce science as a practice (Kind & Osborne, 2017). The research focused on the influence of dialogical argumentation on EK of science since the existing literature on this topic is sparse. Given the identified gaps in physics education, this article has the potential to provide a better understanding, which may be of practical and theoretical importance, in relating dialogical argumentation and EK of science.

The purpose of this study was to examine the effect of middle school students’ engagement in dialogical argumentation on their epistemic knowledge of science. This study was part of a wider research project that promotes the transformation of STEM pedagogy in Ethiopia through argumentation. Specifically, it addresses the extent in which engagement in dialogical argumentation affect middle school students’ epistemic knowledge.

Literature Review

Didactic teaching impedes students’ motivation, epistemic understanding of the practice of science, and eventually their conceptual understanding of various physical concepts (Cavagnetto, 2010). Numerous curriculum reforms in science education summarized that didactic teaching lacks the capability to enhance the scientific know-how of students, and hence recommended a pedagogical reform towards a participatory and collaborative ways of science teaching. Didactic teaching in science also portrays an incorrect perception about what is science, how science works, and how science is practiced by scientists in unveiling the secret working mechanism of nature. Many findings revealed that students are naïve about how scientists know what they know and how the scientific community builds knowledge, owing to the didactic teaching in school science (Manz, 2015).

Clearly helpful approach that is in agreement with contemporary view of student learning as well as the contexts and situations of physics classrooms is hugely demanded. Recently, science education scholars put dialogical teaching as one of best venues for effectively delivering school science. Hence, dialogical argumentation emerges as a means to promote various aspects of scientific understanding, deeper thinking and scientific reasoning (Driver, Newton, & Osborne, 2000).

Dialogical argumentation brings the practice of science in to school science classroom. Taking dialogical teaching to school introduces students to the core standard and practice of science and paves a way to gradually embrace the culture of science (Sandoval, 2005). Dialogic argumentation also consolidates the existing scientific knowledge and constructs new scientific knowledge. Scientific knowledge has three forms. These include content knowledge, procedural knowledge and epistemic knowledge. Science education literatures that focus on procedural and epistemic knowledge were rare. Review of assessment used in different studies supports the claims. Perhaps issues of
accountability contributed towards emphasizing on content mainly. Still higher order thinking was missed. Recent works related to epistemology of science galvanize the interest on epistemic belief, epistemic understanding and epistemic knowledge.

Epistemic knowledge is knowledge of justifying one’s scientific thoughts. Justification relies on a firm understanding of the constructs and distinct features of science and their role in explaining the produced knowledge reasonably (Kind & Osborne, 2017). Epistemic knowledge is knowledge of building scientific knowledge; knowing how we know what we know in science. Understanding the difference between a theory and data (evidence) is epistemic knowledge. It is a crucial component in the process of constructing and justifying the knowledge produced by science, an emblem to the scientific knowledge building enterprise. The know-how about knowledge empowers the functional understanding of students about the nature of science and represents the core practices of science into the student mind. Epistemic knowledge ranges from knowing and recognizing different scientific constructs such as hypothesis and theory to probing meanings to justify and warrant ideas and on into showing various forms of scientific inquiry skills (Hammer & Elby, 2003) and argumentation skills. Hence, in this study it is hypothesized that students with good argumentative skills might have a better epistemic knowledge and subsequently good conceptual understanding of physics and vice versa.

Theoretical Frameworks

Methodology

Convenience and purposive sampling techniques were followed to select the 24-middle school (Treatment group of 408 students from 10 school and the control group of 346 students from 10 schools) around four CTEs in Ethiopia for this quasi experimental study. The selection criteria were English as a medium of instruction, the accessibility of the school, and the willingness of the school to participate in this yearlong study.
The intervention group trained about dialogical argumentation. The training familiarized them about dialogical argumentation and its educational benefits in physics, and introduces the Talking Physics module, its activities, and ways of utilizing these activities to Grade 7 and 8 physics lessons. Talking Physics modules were distributed in the intervention classroom to initiate students’ dialogical argumentation. Data were collected using pre- and post-tests of Physics Reasoning Test (PRT) that assess students’ epistemic knowledge. The questions of PRT were prepared to assess students’ scientific reasoning, by extension their epistemic knowledge.

Findings and Conclusions

This study will analyze the PRT scores to answer the following RQs.

RQ. To what extent does dialogical argumentation affect middle school students’ epistemic knowledge?

Observation from the figure show below revealed that the mean score of students in the intervention group showed slight increase in the post-test (M= 9.32, SD = 4.36) compared to their pre-test score (M= 7.13, SD = 3.16). No difference were observed between the post-test score (M= 8.69, SD = 3.20) compared to their pre-test score (M= 8.64, SD = 4.18) for the control group. The mean PRT score found to progress significantly in the treatment group compared to the control group. In short, this preliminary analysis depicted the influence of dialogical argumentation on middle school students’ epistemic knowledge.

References


WHERE IS THE BIOLOGY? EXPLORING PRE-SERVICE TEACHER PROFESSIONAL LEARNING OPPORTUNITIES
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Introduction

Learning is about how we perceive and understand the world and making meaning of it (Marton & Booth, 1997). Motivation and assessment both occupy a large part of student learning in higher education (Marton and Booth, 1997). Despite many years of research into learning, it is not easy to translate this knowledge into practical implications for teaching. There are no simple answers to the questions ‘how do we learn?’ and ‘how as teachers can we bring about learning?’ This is partly because education deals with specific purposes and contexts that differ from each other and with students as people, who are diverse in all respects, and ever-changing. Owens & Wheeler, (2016) argued that an enormous shift is occurring on how science should be taught, moving away from the recall, recognition, regurgitation of science facts to shifting toward actively engaging students in exploring and making sense of science phenomenon in the world in which they live. The science teacher plays a vital role in mediating this process in the learning context (Chin, 2007). Thus, the need for pre-service teachers to be prepared with the relevant skills for their future classrooms.

The purpose of the study is to explore pre-service teachers’ learning in a life science content and methodology class with teacher educators facilitating dialogic interactions. This paper seeks to address this research question:
How do teacher educators facilitate interaction in their science lectures?

Literature review

Science talk can be conceptualized as occurring in two dimensions during science lessons: organizational and structural (Lemke, 1990). The structural pattern focuses on the manner in which individuals in the classroom are interacting (e.g., who is asking the questions, when students speak, etc.). In whole class discussions, this pattern is most often characterized by some variation of the triadic dialogue: teacher initiates (usually with a question), the student responds (with an answer), and the teacher evaluates or gives feedback. More commonly referred to as the initiate-response-evaluate (IRE) pattern

The meaning of the lesson or content is built within IRE pattern and it is the active construction of meaning by combining and structuring words in scientific ways that constitute science talk (Lemke,
In this case, the focus is not only on what words are being said, but how they are being joined to make meanings in a way that is consistent with the scientific domain. Learning to talk science, therefore, requires that students are taught "how to put together workable science sentences and paragraphs, how to combine terms and meanings, how to speak, argue, analyze or write science" (p. 22). The interactions that emerge in any science lesson are the result of a multifaceted interchange. The purpose and content of the lesson will play a key role in what type of communicative approach is chosen by the teacher during lessons and therefore influence the organizational patterns and teacher contributions to the dialogue (Scott et al., 2006). Considering the chosen analytical framework, the focus of the lesson, which includes both the purpose and content, will determine what types of interactions are allowed during the science talk. The communicative approach of the lesson consists of two dimensions. If the teacher allows for only the scientific explanations to be discussed, this is considered an authoritative approach. On the other hand, if more than one viewpoint is allowed into the discussion, it is considered to be dialogic. In a similar way, the teacher can decide that the dialogue for a lesson will be either interactive or non-interactive. The extent to which students are allowed to participate verbally in the talk determines this dimension. It is also directly related to the manner in which the teacher chooses to intervene during the talk (Mortimer & Scott, 2003). I consider talking to be all forms of communication that take place in the learning context.

Research design and methodology

This study used a qualitative case study approach. The main study involves looking at learning of third year pre-service teachers. I have observed lectures, labs sessions, tutorials and methodology lessons but for this presentation, I am only presenting data from lecture observations. I observed four lecturers for three to six weeks each to collect data for the study. The purpose of the lecture observations was to gain insights as to how teacher educators facilitate classroom interactions to enhance pre-service teacher understanding. The main data collection method was lecture observation of lessons, an audio recording of lectures and notes in a journal.

Data analysis

I used Mortimer & Scott (2003) analytical framework for analyzing meaning-making in the science classroom to guide my analysis of the study.

Lesson transcript

1. Is breathing in and out respiration?
2. When respiration does start and when does it end?
3. When does it relate to photosynthesis?

1. **Lecturer**: What does the ana stand for there?
2. **Student**: Ana stand for putting together or building up
3 Lecturer: The catabolic processes what do you think is happening there?
4 Student: breakdown of substances
5 Lecturer: Photosynthesis and nutrition what do they look like to you?
6 Lecturer: Trophs is a Greek word which means what?
7 Student: feeding.
8 Lecturer: when we say you are an autotroph what does it mean?
9 Students: Chorus - self-feeding
10 Lecturer: what exactly in biology does it mean that the organism feeds itself?
11 Student: it does not depend on another organism to create substances for it to consume as food.

The lecturer opened a dialogic space by putting forth her teacher questioning prompting the student to respond. Opening a dialogic space is central for the development of thinking, creativity, and the ability to learn because comprehension of a problem grows together with the realization of what the lecturer questions demands. The interactive/dialogic approach contrasts with authoritative interactions in that here the teacher listens to, and takes account of, the students' points of view, even though these might be quite different from the school science perspective.

Lecturer: So, photosynthesis is a form of nutrition but for whom? For which group of organism? Student: For autotrophs

Here the lecturer wants students to understand the concept of photosynthesis as nutrition but for plants, as she emphasised that photosynthesis is nutrition but for whom? This kind of interaction, where the teacher leads students through a sequence of instructional questions and answers with the aim of reaching one specific point of view, is typical of an interactive/authoritative communicative approach. The typical form of interactive authoritative talk is the Initiation–Response–Evaluation (IRE) triad, also known as recitation, where the teacher first asks a question (initiation), a student responds and the teacher then evaluates the student's response, letting the student know whether the response is correct. In contrast, in the interactive dialogic talk, the teacher delays judgment, acknowledging the student's contribution by means of neutral feedback. This may involve an Initiation–Response–Feedback Pattern (IRF or IRFRFRF...). This pattern played out when the lecturer initiates the talk by asking

Lecturer: Photosynthesis and nutrition what do they look like to you?

Lecturer: Trophs is a Greek word which means what?
Student: feeding.
Lecturer: when we say you are an autotroph what does it mean?
Students: Chorus - self-feeding
Lecturer: what exactly in biology does it mean that the organism feed itself?
Teacher educators facilitate classroom interaction by the way they engage students in science talk and questions with high cognitive demand which might reveal students understanding of science concepts. The table above indicates how teacher educators facilitate interactions by their classroom talk in the three content lessons I observed.

References


EXPLORING THE USE OF DRAWINGS IN THE TEACHING AND LEARNING OF BIOLOGY

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Introduction

Drawing is an activity that engages the mind. Drawing can be used to evoke mental models for understanding abstract concepts in science subjects like chemistry, physics, engineering, mathematics (e.g. Kurnaz & Eksi, 2015). Other methods that are used to elicit learner mental models involve text which may introduce language related difficulties for learners. The drawing therefore, helps learners represent their thinking without using a lot of text.

This paper reports on a study to explore the use of learner drawings to elicit prior knowledge and to reveal what was learned in a Grade 11 Life Sciences classroom. We addressed two questions:

1. What do learners’ drawings reveal about their prior knowledge of the urinary system?
2. What do learners’ drawings reveal about their understanding of the urinary system at the end of teaching the topic?

Literature and framework

The term, drawing has many meanings depending on whether it is being used as a verb (activity) or as a noun (the product of drawing). In this research the word drawing is used as a noun which relates to the visible representation of the individual’s mental models (Gilbert, 2008). This view of a drawing as a representation of an individual’s mental model was useful for this study in revealing what learners knew about the urinary system from lower grades (prior knowledge) and later what they knew after being taught about the urinary system as a Grade 11 topic. So, their drawings would be a window to see what mental models they had of the urinary system before and after teaching. Meaningful teaching and learning requires an understanding of the learners’ prior knowledge. This knowledge is used to inform the teacher to prepare relevant lessons. So, in this case learners’ drawings would provide the teacher with this prior knowledge.

In South Africa, the third paper in the Grade 10 and 11 Life Sciences examination is practical skills based. This paper contributes 15% of the theory examination (Papers 1 and 2 each contribute 30%) (DoE, 2012, p. 69). The practical skills tested include various kinds of drawings as visual representations of the leaners’ mental models. These include tables, graphs or diagrams of biological structures. This use of drawing as a tool that reveals learner knowledge is supported by studies conducted in and outside of South Africa (e.g. Dempster & Stears, 2013; Reiss & Tunnicliffe, 2001).
Our study investigated how Grade 11 Life Sciences learners used drawings to reveal their knowledge of the human anatomy, in this case the urinary system. The urinary system as a topic is introduced at Grade 9 according to the curriculum document (DoE 2012). The topic continues at Grade 11 to include details of the kidney structure and function. Therefore, learners are expected to be able to link their existing knowledge from Grade 9 to the new knowledge introduced at Grade 11. It would therefore be useful for the teacher to know the learners’ existing knowledge in order to prepare lessons that are relevant. According to the inclusion policy teachers are expected to conduct diagnostic tests to determine what the learners know before they are taught. In this study drawing was used diagnostically to determine the learner’s knowledge of the urinary system before teaching.

The use of drawings in Biology also promotes careful observation, representation of what is observed and making inferences (Landin, 2015). Thus, drawings can also be a tool for learning. Learning involves the process of making meaning of the taught concepts by linking them to the existing/prior knowledge (Hewson & Hewson, 1983). Studies that have been conducted on the use of drawings in science learning employed social constructivist approach since it recognizes learning through social interaction as in group-work (Vygotsky, 1978). Similarly, this study adopted the social constructivist approach. Our learners were English second language speakers and struggled with both the written or oral communication about biological concepts which could hinder learning for some. The use of drawings would allow the learners to communicate using less texts and verbal modes. We also drew from the Dual-coding theory of memory on learning to make sense of learning from and with drawings.

**Dual-Coding Theory of Memory on Learning**

According to the Dual-coding Theory, the speech/verbal and the nonverbal information is used alternatively inside the learner’s brain. It states that there are two subsystems which are verbal or “logogens” and nonverbal also called “imagens”. If a learner talks about a word, ‘dog’, as an example of logogens, then s/he visualizes a dog in her/his mind and that would be an imagen. It does not matter if the learner would be required to draw the dog or just write the word dog. The learner will realize that there is a relationship between the word and the mental image s/he visualizes. The theory posits that whenever a picture or diagram is seen, verbal representations are also visualized (Paivio, 1986). According to the Dual Coding theory there are three types of processing: (a) representational, which involves activation of verbal or non-verbal representations directly, (b) referential, where the verbal system gets activated by the nonverbal system or vice-versa, and (c) the associative processing, through the activation of representations within the same verbal or nonverbal system (Paivio, 1986). Classroom instruction may require one or all of the three kinds of processing. We hoped that learners would have mental images of the urinary system as part of the human body systems as they respond to the activities, they do prior to drawing it on paper and the logogens would follow during peer discussions. The learners would correct their imagen (drawing) during the drawing activity (Paivio, 1986). The drawing would give the learner’s representation of their understanding and also highlight their mistakes. This way the drawing acts as a learning tool and enables the learner to identify and correct his/her mistake.
Methods

A class of 52 Grade 11 Life Sciences learners in a suburban school was invited to participate in the study. The learners were asked to draw the human urinary system. The assumption was that the learners would remember the urinary system from previous grades and from any other sources of their experiences. It should be noted though, that the learners had covered content on the digestive and breathing systems a few weeks prior to this study. The first author who was their teacher, then taught the topic, the human urinary system. After teaching, the learners were given the same figure and again asked to draw in the urinary system.

Learner work was analysed to determine the knowledge revealed by drawings before and after teaching and thus, examine the value of drawings in the teaching and learning of the topic.

Results and discussion

In this section attempts we present data that answers the question ‘What do learners’ drawings reveal about their prior knowledge of the urinary system?

Of the 52 learners, forty-three drew some system and nine (9) did not draw at all. Of the 43 drawings, some had the urinary system drawn separately while others combined it with other system as if they were a single system (See the Table 4.1 below).

<table>
<thead>
<tr>
<th>The System Types that the learners Drew</th>
<th>Number of drawings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Urinary system only</td>
<td>7</td>
</tr>
<tr>
<td>2. Urinary system + breathing- &amp; Digestive-system</td>
<td>16</td>
</tr>
<tr>
<td>3. Breathing- &amp; Digestive-system linked</td>
<td>8</td>
</tr>
<tr>
<td>4. Breathing- or Digestive –system singles</td>
<td>12</td>
</tr>
</tbody>
</table>

The instruction was to draw the urinary system only. Seven (7) learners were able to do so. Another 16 learners drew the urinary system with additional systems. So 23 learners knew what the urinary system was and were able to draw it. Figure 4.1 below is a pie chart which gives a visual representation of the data in Table 4.1 above in percentages.

Figure1. Summary of the proportion of learners who presented each type of drawing.
According to the data, only 16% of the learners could recall reasonably accurately the urinary system from previous grades, while 37% remembered something but tended to link it inaccurately with other systems. The rest, 47%, could recall the urinary system at all, some drawing the breathing and digestive systems together and others drawing them separately. Below are some of the diagrams that the learners presented.

Figure 2: Drawings by two students who had a reasonably accurate recollection of the urinary system.

Figure 3: Drawings by two students who did not remember the urinary system.
Due to space limitation in this abstract we do not present data that answers the second question. At SAARMSTE 2019 we will present other evidence from learners’ drawings to answer both our research questions.

Meanwhile we conclude that this study demonstrates the potential for drawings as an important tool to elicit learner prior knowledge and to assess learning. Further research could explore the role of drawing and drawings in learning.

References


INVESTIGATING THE POTENTIAL IMPACT OF MAKING PEDAGOGICAL REASONING PUBLIC ON ONES’ TEACHING OF A BIOLOGY TOPIC: A Self-study

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Introduction

A teacher’s planning which involves the choice of content to be taught and how to teach it is influenced by that teacher’s pedagogical reasoning (Blömeke & Delaney, 2012). To most teachers, due to teaching the same content year in and year out, teaching tends to become a routine practice that ceases to involve any conscious thinking and reasoning. However, my experiences show that taking teaching as one of those day to day routine exercises is a pedagogical blunder because the teaching of a topic each time is a unique experience as it involves new students with different learning capabilities, different prior ideas and different levels of motivation to learn. It may therefore be problematic for a teacher to teach the same topic in the same manner every time. As argued by Boshier and Huang (2008), progressive education settings should consider teaching and learning as a dynamic process that entails both students learning and continuous life-long teacher learning through cycles of continuous teacher reflections focused at improving the teacher’s pedagogical reasoning. The incorporation of reflective practices has a potential role of providing feedback loops into the teacher’s pedagogical reasoning which in turn has the potential to enhance continuous life-long learning and hence professional growth. This was the motivation for this study in which I made my pedagogical reasoning when I was planning the teaching of the topic of evolution public with the aim of finding out how that would impact teaching practices. The question(s) that guided this study were:

1. To what extent does making my pedagogical reasoning public impact my teaching of a biology topic?
2. What are the benefits and challenges (if any) of using a self-study approach as a methodology for enhancing my pedagogical reasoning when planning and teaching a biology topic?

Theoretical framework

The focus of my self-study was to find out the potential impact on my teaching of making pedagogical reasoning public and engaging in reflective practice. To scaffold my research, I opted for a theoretical framework based on the model of pedagogical reasoning and action as propounded by Shulman (1987). This model involves a cycle of six actions namely comprehension, transformation, instruction, evaluation, reflection and new comprehension. In this study, the cycle entailed my understanding of
the evolutionary genetics content knowledge (comprehension), convert this subject content knowledge into a form that is easy for students to understand (transformation), teaching this subject content (instruction), objectively evaluating my own performance and students’ learning progress (evaluation), reflecting on the strengths and weaknesses of the pedagogical action that I undertook during the lesson (reflection), and picking up new understanding of pedagogical ideas from insights that arise due to the teaching efforts conducted [new comprehensions] (Shulman, 1987; Bishop & Denley, 2007).

Methodology

This self-study followed the five self-study methodological foci points as put forward by Samaras (2011, p. 10) which are that a self-study a) is a personal situated inquiry, b) is a critical collaborative inquiry which focuses at making new insights for enhancing student learning in the company of others c) is a knowledge generation and presentation exercise, d) is a transparent and systematic research process, and e) aims to improve teacher researcher learning. I used these five methodological foci points to structure my research approach, data collection and analysis.

Participants

The participants included me as the researcher and the subject of investigation, my three colleagues who helped with the listing of concepts to be taught under the topic evolutionary genetics and a biology expert who helped with the face validation of the evolutionary genetics content I chose to teach and also played the role of a critical friend.

Data sources and examples of data collected

The data sources for this study included my lesson plans, discussions with colleagues which were audio-recorded and transcribed and journal entries of my planning, my pedagogical reasoning during planning, feedback and comments from the content expert and my reflections. Below, I provide examples of data in the form of i) journal entries and 2) an excerpt from a transcribed discussion with a colleague.

1. Journal entry 1 (20/08/2017): To understand the topic of evolution, requires a robust understanding of genetics topics and every year when I teach the topic of evolution, I spend a great deal of time revising some genetics concepts such as variation. I wonder what would happen if instead of teaching genetics and evolution as two separate topics, I combine the two and teach them as one topic-evolutionary genetics 😊.

2. Excerpt of a transcribed conversation with Josh (a colleague):
   Josh: Since there is no topic called ‘evolutionary genetics in the CAPS document, how you are going to come up with content for teaching in this particular topic?
   Author: I envisage that the CAPS syllabus document could be a good starting point as I try to plan my content for teaching. I will review all the evolution and genetics content in the CAPS document, compile a list and give it to a biology content expert for face validation.
Description of the data collection and analysis process

In self-study, data collection and data analysis are not linear processes whereby you collect data first then do data analysis after, rather data analysis occurs concurrently with data collection. Data collection and analysis involved cycles of journaling, reflecting and discussing with colleagues and critical friends during which insights were emerging from my teaching experiences. Below I present an excerpt that shows the data collection and analysis process.

In my list of concepts to be taught under the topic that I had coined evolutionary genetics, I had omitted Lamarck’s ideas. My reasoning for leaving out Lamarck’s ideas was that these ideas have been discarded by scientists and one can still understand evolutionary genetics by natural selection without having to learn them. However, expert A’s feedback on my list provided me with a different way of looking at Lamarck’s ideas that I had never thought of before. Below, I present my conversation with the content expert Edina.

Edina: Firstly, I want to point out that your reasons for leaving out Lamarck’s ideas should actually be the reason for including it in your teaching.

Author 1: What do you mean?

Edina: The fact that these ideas were at some point accepted by the scientific community and then got discarded after the gathering of more evidence depicts the true nature of the scientific method that students of science know. Therefore, by not exposing students to this information you are denying them knowledge about the nature of science.

Author 1: Nature of science? This is something that I have never considered in my teaching. I have always thought that nature of science is a course that is taught at university and never thought that it is or can be part of one’s teaching of science.

My reflections on Expert A’s comments on Lamarck’s ideas (Journal Entry: 28/08/2017): There is a lot that I can say about the nature of science when teaching evolutionary genetics e.g. that science has a history and that the theories that students are learning today like the cell theory and the chromosomal theory were all developed piece by piece. Why didn’t I think about this before?

Based on my discussions with the content expert and on my reflections, my pedagogical reasoning has been enriched. Now Lamarck’s ideas that I had initially excluded from the content to be taught, forms part of what I teach in the topic evolutionary genetics as part of the history and philosophy of science, which some scholars (e.g. Jensen & Finley, 1995) point out is an effective way to teach because of its story-telling approach which most students find appealing when learning new ideas. A consideration of Lamarckian ideas even without mentioning Lamarck’s name has enabled me to come up with teaching strategies that tackle the erroneous thinking that organisms evolve because of need. My inclusion of Lamarckian ideas has provided me with a way of redressing possible
teleological and anthropomorphic thinking which is linked to Lamarckian interpretation of concepts and has been found to be prevalent in children (Bishop & Anderson, 1990).

**Conclusion**

Exposing my pedagogical reasoning to others transformed my thinking and ushered in a new comprehension of evolution and how to teach it. Making one’s pedagogical reasoning public and incorporating reflection in one’s professional practice using the methodology of self-study has the potential to enhance life-long learning as one can get lots of fresh and effective pedagogical ideas.

**References**


I-TSPCK NEITHER TPACK NOR E-LEARNING
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Introduction

In recent years, teacher professional knowledge has been challenged to include knowledge needed for the delivery of e-learning due to advances in technology and changing social demographics. Teacher education institutions have to prepare for graduate teachers in the 4th industrial revolution. Thus, designing alternative curricula at a fast-changing pace in order to match the disruptive innovations (Xu, David and Kim, 2018). Knowledge of subject matter, transformed by teacher’s reasoning to make the topic comprehensible to students has become known as Pedagogical Content Knowledge, PCK. With increasing demand for the introduction of e-learning and the related technologies, this study asks the question, what form would PCK, particularly Topic Specific PCK, as the accepted teacher knowledge for teaching science topics take, when operating at the e-learning dimension? This question is in line with the observation that advances in educational research and society in general have an influence on the definition of teacher knowledge (Koehler and Mishra, 2005).

Literature Review

In the mid-1980’s, Shuman (1986) described teacher knowledge to include content knowledge, curricular knowledge and pedagogical content knowledge as the teacher knowledge most relevant to the teachability of content. In today’s terms, the teachability has increasingly included electronic platforms with many bells and whistles that are affording increased learner interactivity. Shulman (1986) alluded to this by pointing to the potential influence of a well-developed framework to implement PCK. Technology used for learning, generically termed e-learning, has changed the form of accessing content, skill acquisition and assessment, allowing greater flexibility for unique student learning (Nasir, 2017). In acknowledgement of the new need for teachers to acquire knowledge of the use of the electronic tools, Koehler and Mishra (2005) proposed a theoretical framework, called Technological Pedagogical Content Knowledge (TPACK). TPACK mainly assist teachers to acquire the knowledge to use electronic gadgets for teaching purposes. While TPACK is welcomed and valued, it is however challenged by the rapidly changing technologies and differing software designs, negatively impacting the learning curve of teachers expected to implement e-learning. In this study, we warn that Shulman’s (1986) missing paradigm in the development of teacher professional knowledge is raising its head anew, lest we move our understanding of TSPCK (Mavhunga, 2012) into a version that is congruent with learning on electronic platforms. At the intersection of TPAK and TSPCK, in the
broader e-learning realm, there lies a gap for a pedagogically reasoned integration of technology, not just knowing how to use gadgets as TPACK describes, nor use TPACK as the knowledge of the TSPCK component of representations. This study is attempting to introduce a new construct, eTSPCK electronic-Topic Specific Pedagogical Content Knowledge, which will enable teachers to exercise component interactions within the realm of an electronic platform. Here we envision, the knowledge for technology (TPAK) being used beyond the natural enhancement of the TSPCK component of representations, but to be seamlessly infused within the TSPCK components, transforming content delivered within the e-learning environment. We acknowledge the many challenges that lie ahead as we seek to unpack what i-TSPCK would fully look like, however, see the study as paving a needed pathway for provision of science education into the 4th industrial revolution.

Research Design

The research design will have two parts. The first part aims at developing a conceptual argument for defining i-TSPCK as a theoretical construct. According to Kane (2012), the process for construct validity requires a combination of a conceptual argument and a statistical argument. For the conceptual argument, a literature review unpacking what e-learning is from a broader perspective, what TPAK and TSPCK are will be conducted. The key focus from the review of these three constructs will be to draw a logical location for i-TSPCK. The argument for statistical or empirical argument will be based on observing a sample of 4 physical science expert teachers who are members of a Professional Learning Community (PLC) currently teaching in schools practicing e-learning in the Johannesburg, Gauteng Province. The PLC will under my observation discuss and plan for teaching of a specific topic as a group. Their delivered lessons will be video recorded for extraction of how pedagogical transformation of knowledge is evident in the context of e-learning. Extracted episodes will be analysed using in-depth qualitative method and compared to findings emerging from the literature review. It is hoped that a clearer picture of the components or features constituting e-TSPCK would emerge. This will enable, in consultation with the PLC, the development of a tool to capture and portray i-TSPCK, along the lines of the Content Representations (CoRe).

The second part, will entail developing and implementing an in-service teacher intervention programme that would introduce the newly defined i-TSPCK theoretical construct with a given specific topic in chemistry. The programme would target about 20 practicing physical science teachers. Pre and post-tests on the newly developed i-TSPCK will be administered. A subset of 4 teachers will be followed for classroom observation in an e-learning setting. Their lessons will be video recorded and analysed for evidence of i-TSPCK as defined from Part 1. It is hoped that the findings from this study will contribute the kind of knowledge needed for teaching science teachers for the digital future society.

Through the snap paper presentation, we hope to elicit discussion and feedback on the conceptualization of i-TSPCK and the research design of the study.
References


EXPLORING TEACHER REFLECTIONS WITHIN A NATURAL SCIENCES PROFESSIONAL LEARNING COMMUNITY: Moving Teachers Through their Zone of Proximal Development.
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Many teachers seek ways to improve their practices so as to improve learner understanding. Reflection on practices allows teachers to be mindful of choices made and to restructure these in future lessons (Zeichner & Liston, 1987). However, teachers in developing countries struggle to reflect on their practices (Chikamori, Ono, & Rogan, 2013). Fullan (1991) asserts when teachers work within a professional learning community (PLC) focused on reflection it was possible for teachers to change their practices. We were interested in tracking participation over two years, of two Natural Sciences teachers within a PLC. The focus of the PLC was to reflect on working with learner prior knowledge within the content areas: Effects of an electric current (EoEC) and light. Our research question is: when reflecting on two content areas within a PLC, how (if at all) does teacher participation and level of reflection within a PLC change?

Literature Review

We have taken our definition of a PLC from the work of Chauraya and Brodie (2017) a PLC is defined as a space where teachers meet regularly with the purpose of changing practices through their collective interaction. Vescio, Ross, and Adams (2008) claim effective PLCs are grounded in two assumptions: first active participation is needed for content and pedagogic content to be enhanced and second reflection is dependent on shared experiences.

From their work in the US, Zeichner and Liston (1987) developed three levels of teacher reflection: moral craftsperson, craftsperson and technician. A teacher reflects at the technician level when they are concerned with completing that which has been set by others. A craftsperson reflective teacher considers the educational reasons for their practices. They contemplate whether and how well educational goals are achieved. A moral craftsperson reflects on the ethical implications of what has taken place within a context. O’Sullivan (2002) found that Namibian teachers in her study reflected at a level lower than the ‘technician’: Teachers in her study were able to identify problems with practice and not suggest solutions. She coined the term ‘basic technical awareness’. We will refer to teacher reflections at this level as ‘basic technician’.

Theoretical Framework
The writings of Vygotsky (1978) on social constructivism are the theoretical lens guiding our research particularly the notion of the zone of proximal development (ZPD) where learners move from what they can do on their own to that which they can do with help. However, our research is focused on how teachers move through their zone of proximal teacher development (ZPTD), (Warford, 2011). Warford maintains when teachers work collaboratively with peers, opportunities are created where they assist each other to move through their ZPTD.

Methodology

Our qualitative study, was conducted in a suburban high school in Gauteng. We are reporting on the participation of Luke an experienced teacher (30 years) and an inexperienced teacher Kate (3 years) within the PLC (over 2 years).

An action research methodology was used to collect data. Five cycles in total have been completed: cycles 1, 2 and 3 in year 1 with cycles 4 and 5 in year 2. Cycle 1 focused on baseline practices. Cycles 2 and 4 were concerned with the same content: EoEC. Whilst Cycles 3 and 5 focused on working with the content “light”. Each cycle included the following parts: act (teaching in class), observe (by the first author), reflect and plan sessions (in PLC meetings after school).

Reflect and plan meetings were audio recorded and transcribed. Within these meetings teachers reflected on aspects of their practice needing restructuring. It was therefore possible to identify reflective episodes (REs). A RE occurred where teachers discussed an aspect of teaching needing improving. The level at which teachers reflected within the REs has been coded using the levels of reflection (moral craftsperson, craftsperson, technician and basic technician). A teacher was only coded once within a RE, this at the highest level of reflection. A distinction was also made as to whether the teacher initiated the RE or merely participated in it. No moral craftsperson reflections were coded.

Results

Table 1 Levels of teacher-initiated reflection Episodes

<table>
<thead>
<tr>
<th></th>
<th>Reflect 1</th>
<th>Plan 2</th>
<th>Reflect 2</th>
<th>Plan 3</th>
<th>Reflect 3</th>
<th>Plan 4</th>
<th>Reflect 4</th>
<th>Plan 5</th>
<th>Reflect 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luke</td>
<td>Craftsperson</td>
<td>8</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Technician</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Kate</td>
<td>Craftsperson</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Technician</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Basic Technician</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Luke took the lead in PLC meetings focused on the content EoEC, where his content and pedagogic knowledge was sound. Luke participated in most REs, initiating many. From the first PLC meeting Luke reflected at a craftsperson level. However, the same could not be said regarding his participation and level of reflection in PLC meetings focused on the light content, where his content knowledge was less sound. Whilst Luke participated in most REs, he did not initiate many. His level of reflection was mostly coded basic technician in year 1 and technician in year 2.

Kate was an inexperienced teacher who attended all PLC meetings. Initially, her participation was limited, contributing to only one RE in the first meeting. It was in her third PLC meeting where she initiated her first RE, at the level: craftsperson. Her participation in reflective episodes in the first year’s meetings (focused on EoEC) were coded predominantly as basic technician. In the year 2 of the same content, she initiated four reflective episodes and participated in many REs. A similar trend was found when tracking Kate’s participation and level of reflection with the light content of work. She did not initiate any reflective episodes in year 1, although she did participate in some REs reflecting at the technician and basic technician level. In year 2, Kate initiated two REs both at the craftsperson level.

Discussion and Conclusion

PLC meetings were dependent on a teacher with sound content and pedagogic content taking the lead. With the content area EoEC, Luke took to the lead. He was motivated to share his content and pedagogic knowledge with the group of teachers. He was also keen to improve his own practices through careful reflection and planning. Initiation of REs was dependent on the lead teacher. The lead teacher was able to design activities and predict learner misconceptions allowing the group to work with LPK. Further, when reflecting on the activities the lead teacher not only initiated most of the REs, but the level of the reflections was high.

Where teacher content knowledge of a topic was lacking, initially teacher participation and level of reflection was low. However, with continued attendance at PLC meetings both teacher participation and the level of reflections increased. It would seem lead teachers were helping teachers move...
through their ZPTD. These findings are in contrast to those of Chikamori et al. (2013) who reported teachers showing poor participation in successive reflection sessions in their lesson study.

Due to the diverse content in the Natural Sciences curriculum it seems unlikely that one teacher would be an expert in all topics. A teacher with sound content knowledge in one topic of the curriculum may not necessarily be a content specialist teacher in another content area. Findings from our study show that while a lead teacher emerged for the content EoEC in initiating REs, he did not emerge as the lead teacher for a different topic. As noted by Brodie (2013) the importance of a leader within a PLC cannot be overemphasized. This person needs skills and knowledge to ensure that the collaborative nature of the PLC is maintained, by ensuring a safe and trusted environment.

The Department of Education would do well to identify leaders who are motivated to manage effective PLCs. These teachers should be trained on what it takes to manage an effective PLC. Having been trained, lead teachers would establish PLCs within their school or district, who meet on a regular basis. Working collaboratively within a PLC teacher would assist each other in their practices

References


PHYSICS TEACHING WITH DIALOGICAL ARGUMENTATION IN ETHIOPIAN CLASSROOM CULTURE IN UPPER PRIMARY SCHOOLS

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Abstract

In the last three years, an attempt was being done to introduce dialogical teaching in to Ethiopian education system. This study will be conducted with the purpose of investigating the nature of existing classroom culture of physics teaching and identify factors that constrain the success of dialogical teaching in physics classrooms. To achieve the purposes, a multiple case study design will be used. Schools from three regions of Ethiopia will be included in the study. Data will be collected using interview and classroom observation through recorded videos and socio-cultural discourse analysis will be used to analyse the classroom talks that teacher and students mainly used to communicate.

Introduction

In the last three years, an attempt was being done to introduce dialogical teaching in to Ethiopian education system. This big endeavour was introduced by the project “Transforming the Pedagogy of STEM Subjects” (TPSS). The project aimed at introducing educational innovation in the pedagogy of teaching physics in primary schools and colleges of teacher education.

Dialogical teaching which is a student-oriented approach supports the view that knowledge and understanding comes from testing and analysing ideas using peer to peer or teacher-student communication. The existence of dialogic approaches to learning and teaching is based on the idea of Russian psychologist Lev Vygotsky who recognised language as the driving force behind cognitive development from the claim that the function of language during interaction such as explaining, asking question, giving answer and reasoning stimulates cognitive process (Vygotsky, 1978). Studies on argumentation in science teaching and learning are mainly focussed on three main issues. The first group of researches is focused on the investigation of the benefits of argumentation in science learning (Osborne et al, 2007; Hajhousseiny, 2012). The second group of argumentation studies deal with the development of strategies to enhance teachers’ capacity so as to promote argumentation in science classrooms (Osborne, Erduran & Simon, 2004). The third group of studies focussed on the evaluation of quality of argumentation (Osborne et al, 2004).

In these clusters of studies, the potential benefits of dialogical argumentation in science learning, various ways of examining quality arguments and various ways to improve teachers’ skill in
promoting argumentation in science classrooms are explored. Despite the many barriers to implement innovative practices, the findings of these studies are all promising.

Even if the recognition of the importance of dialogic approaches to teaching and learning and their potential for raising standards appear to be spreading in the literatures, the establishment of dialogic approaches to classroom discourse is not easy. Regarding this, Lyle (2008) suggested that research is needed into what classroom processes best support dialogic practice in classroom settings.

As teachers are the main practitioners of teaching, they can be considered as the most influential factors that determine the proper implementation of educational innovation in classroom. Therefore, this study will attempt to assess the nature of existing classroom culture of physics teaching in order to identify factors that inhibit the success of dialogical teaching in physics classrooms. Accordingly, this study will answer the following main questions.

How classroom culture of physics teaching and learning is described? How does the existing classroom culture support argumentation? What are the factors that constrain a move from existing classroom culture to a classroom culture that supports dialogical teaching?

**Theoretical Framework**

The conceptual framework that informed this study includes Bourdieu’s field theory and sociocultural learning theory (Vygotsky, 1978; Bourdieu, 1993). While the field theory provides the necessary lens to conceptualize classroom culture, the sociocultural perspective is used to understand the influence of culture and social interaction on students learning and guides the analysis of classroom interaction.

In this study, classroom is conceptualized as a field situated within the larger field of school and even broader field of the community. In viewing the classroom as a field, the actors are students and teachers. These actors (students and teachers) are interacting with each other and with the physics content in diverse ways to create classroom culture. The relationship between actors and classroom culture is reciprocal: practices of actors influence and are part of classroom culture just as classroom culture influence the practices of actors (Jams & Biesta, 2007).

Because teachers conceptualize and organize their lessons according to activities, classroom tasks (activities) can serve as one element in the construction of classroom culture (Valli & Chambliss, 2007). Moreover, classroom culture cannot be thought as something that stand by itself. An ongoing dialogue and negotiation takes place between teachers, students, subjects (in this case, physics), and context (Kirkebaek, Du & Jensen, 2013). This means that the context of the classroom determines the culture created in the classroom.

Therefore, the conceptual model of classroom culture in this study represents five major interrelated components: classroom practices of teacher, classroom practices of students, classroom tasks,
classroom context and interaction among them. Accordingly, these elements will be the units of analysis in this study.

*Figure 1.1: Conceptual model of classroom culture*

**Research design and methods**

This study is mainly concerned with exploring human practices, more specifically classroom practices of teachers and students that create classroom culture. To explore the nature of existing classroom culture, data will be collected from students and teachers using classroom observation through video recordings and interview. Hence, the study will employ multiple case study design.

The data in the study will be analysed by qualitative and quantitative means. In the study, teachers’ and students’ classroom talk will be the main focus of the analysis. Students’ talk will be analysed with respect to three dimensions: function of verbal language, cognitive processing and social processing. The functional analysis of students’ verbal interaction will focus on the purposes on which the verbal language is used in a given context. Pre-determined functions of classroom talk that are identified by Fourlas and Wray (1990) will be used to analyse students’ classroom talk.

In the analysis of cognitive processing, the way in which students’ approach and process learning tasks or activities in their group will be analysed. In the analysis of cognitive processing, students talk will be examined with respect to whether they use routine way of tackling a task (procedural processing) or they use their critical thinking for solving a given task (interpretive or exploratory processing).

The analysis of social processing aims at characterizing the social relationship and types of participation in the interaction group. The different mods in which social processing is often constructed in peer group interaction are collaborative (working in collaboration with others), tutoring (explaining for the purpose of assisting), argumentation (explaining with justification), individualistic (working individually), dominative (existence of imbalance in students’ social status or power), conflict (disagreement among members) and confusion (lack of shared understanding) (Kumpulainen & Wray, 2002). Teachers’ classroom talk will be analysed based on five main aspects of classroom practice including classroom interaction, teacher pedagogy, feedback, assessment and classroom management.

**References**


TOWARDS STIMULATING AFRICAN “LEARNER INTEREST”: A Conceptual Framework for Reinforcing Metacognition through the Inclusion of Technology as Praxis in Physical Science Classrooms
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In a report entitled “The Maths and Science Performance in South African’s Public Schools: Some Lessons from the Past Decade” the Centre for Development and Enterprise (CDE) summarises its main findings, as follows:

“The number of learners with the potential to pass science is considerably lower than expected. The key issue in respect of science is learner interest. Schools can be placed in two broad categories with respect to performance in maths and science: Independent and Quintile 4 and 5 schools; and Quintile 1, 2 and 3 schools. Passes in mathematics and science are heavily concentrated in the first category of schools. In other words, 90% of our schools are still failing to meet the minimum performance standards in mathematics and science education, thus undermining the potential of millions of young South Africans and hampering national development. This means that we have to deal with the tough but vital issue of the accountability in terms of learner performance.”

(CDE, 2010 p. 12)

The Trends in International Mathematics and Science Study (TIMSS) study confirms these observations in that South Africa still finds itself amongst the lowest five countries (Ngoepe, 2016). Graven (2013) confirms that maths and science education in South Africa operates in ways that leave a significant proportion of marginalised learners with negative experiences and inadequate preparation. She further adds that the challenges are both historical and systemic, in that the learners most disaffected by the current system are mostly black or first-generation high school learners. Hence this conceptual paper seeks to report on the development of a framework utilising aspects of metacognition that stimulate learner interest in the Physical Sciences through the inclusion of technology in South African classrooms as derived from empirical research reported on in the literature.

Howie (2003) reported on teachers succumbing to poor performance and increasingly addressing it with teacher-centred, transmission mode pedagogies. Twelve years later, Kaya, Kablan, Akaydin and Demir (2015) confirm that this problem still persists. Learner boredom, lack of interest and increasing gaps in knowledge in the Physical Sciences as a result of teacher-centred approach is pervasive. Most educators (and parents) complain that learners have an intrinsic interest on social media since cell
phones are widely available amongst the youth. Furthermore, they point out that learners have no interest in engaging with school learning outside of school. The questions then become: Are teachers teaching in ways that attract learners to learning? And how can teachers harness learner interest in technology into teaching and learning so as to positively impact on learner performance?

It has been shown that technology provokes interest and re-directs learner focus to their studies in multiple ways. Hence, this study seeks to contribute significantly by developing a conceptual framework of how ICT integration in the science curriculum helps to redirect learners to self-study in ways that underpin the theory of metacognition which advocates for mechanisms of self-regulation. In so doing we add to a body of research aimed at the integration of technology for science instruction in South African schools. In contexts where science resources are lacking, or where teacher preparation is a challenge, research shows that the integration of ICT can assist learners to become more thoughtful about their own learning. Such interventions help learners to go beyond thinking with regards to thought processes that are not directly visible in order to improve their metacognitive performances. As learners become more aware of themselves and have the requisite tools to take charge of their own learning they proceed towards a journey of lifelong learning. This is because metacognitive strategies has been shown to enable more efficient learning because they help with information sourcing, and additional resources, so as to provide different approaches to problem-solving (Bruning, Schraw, & Norby, 2011).

An integration of four theoretical frameworks was used in the development of the conceptual framework. They include, Education for Self-Reliance (ESR, Nyerere, 1967), Piagetian Cognitive Theory, Vygotsky’s Social Constructivist theory and Metacognitive Theory. ESR is a contextually linked framework woven as an underlying principle to Metacognitive Theory in terms of learning as self-regulation commensurate with the purpose for learning in the South African context. In addition, Metacognitive Theory is a central construct that conceptualises learning within a constructivist approach to teaching and learning. The four frameworks are complimentary and provide a more focused approach to Metacognition as a general theory.

In this study, Flavell’s framework is adapted for the African context (Flavell, Miller, & Miller, 2002). This particular framework is chosen because Flavell is a leading figure in research on metacognition, and his work serves as the foundation for many subsequent frameworks. Flavell et al., (2002) distinguish between three major components of metacognition: metacognitive knowledge (MK), metacognitive skills (MS; e.g. Efklides, 2006; Veenman et al., 2006) and metacognitive experiences (ME). An analysis of 178 research articles provide the following useful concepts within the three domains as explicated in Table 1 below.
Table 1: Clusters of constructs that are studied in connection to metacognition in science education

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Construct</th>
<th>Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Content knowledge (21.9%); science concepts (21.3%); conceptual understanding (21.3%); conceptual change (9.0%); knowledge construction (6.2%); misconceptions (6.2%); and models (5.6%)</td>
<td>Conceptual knowledge</td>
</tr>
<tr>
<td>2</td>
<td>General thinking skills (23.6%); problem-solving (22.5%); inquiry learning (21.9%); specific thinking skills (15.2%); laboratory (12.4%); and experiments (7.3%)</td>
<td>Higher-order thinking and inquiry learning</td>
</tr>
<tr>
<td>3</td>
<td>Personal epistemology (13.5%); prior knowledge (11.2%); self-regulated learning (10.7%); motivation (10.7%); regulation (10.1%); and self-esteem or efficacy (7.9%)</td>
<td>Personal epistemology and self-regulated learning</td>
</tr>
<tr>
<td>4</td>
<td>Science texts (11.2%); reading (11.2%); scientific literacy (5.6%); and explanation (4.5%)</td>
<td>Reading and literacy</td>
</tr>
<tr>
<td>5</td>
<td>Reflection (20.2%); academic achievements (11.2%); learning strategies (10.7%); learning experiences (6.2%); attitudes (5.6%); nature of science (5.6%); and self-assessment (4.5%)</td>
<td>Learner-related dimensions</td>
</tr>
</tbody>
</table>

Figure 1. A map of the recurring constructs studied in the field of metacognition in science education as depicted in the literature.

These constructs show a direct link with how metacognitive instruction through the mediation of technology can impact and reverse the challenges learners in Physical Science in South African
classrooms experience. In this way a conceptual framework is being developed for consideration in the South African context.

REFERENCES


Background

Erinosho (2013), explained that Physics is basic for understanding the complexities of modern technology, and essential for technological advancement of a nation and this aspect of science is making significant contribution to many of the inventions that are shaping modern day, and has helped to explain many of the events being encountered in everyday life. Despite its importance, physics remains one of the least favored science subject among students generally, hence very few learners would like to study physics at institutes of higher learning. In the University of Eswatini (UNESWA) for example, the Departments of Physics and Curriculum and Teaching continued to witness paucity of students, which is one of the reasons there is a serious shortage of physics teachers in secondary schools.

Table 1.1. Number of Physics Students at the University of Swaziland (UNISWA), for the academic years 2012 to 2017.

<table>
<thead>
<tr>
<th>Programme/Academic Year</th>
<th>B. Sc. Year 1</th>
<th>B. Sc. Year 2</th>
<th>B. Ed. Sec. Year 1</th>
<th>B.Ed. Sec. Year 2</th>
<th>B. Ed. Pri. Year 1</th>
<th>B. Ed. Pri. Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012/2013</td>
<td>52</td>
<td>19</td>
<td>11</td>
<td>1</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>2013/2014</td>
<td>45</td>
<td>13</td>
<td>20</td>
<td>1</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>2014/2015</td>
<td>39</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>2015/2016</td>
<td>79</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2016/2017</td>
<td>100</td>
<td>3</td>
<td>7</td>
<td>3</td>
<td>26</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 1.1 shows for example that in the academic year 2012/2013, 52 BSc. and 11 B.Ed. Students enrolled for the programs and yet only 13 and 1 chose to continue with Physics in the following academic year 2013/2014 respectively. This has been a generating concern among science educators, and researchers are increasingly exploring why students avoid the subject.

Statement of the Problem

Having students’ views about their difficulties in the learning of Physics can influence the choice of curriculum, implementation of curriculum, and the nature of evaluation in physics courses (Ornek, Robinson and Haugan, 2008, Carter and Brickhouse, 1998).
Science (especially Physics) is a compulsory subject for all learners in high schools and yet there are few learners who would like to pursue their studies in Physics at tertiary level. This study will analyze the implementation of the Physics section of Physical science syllabus at High school to understand what might influences the learners not to pursue Physics at tertiary level.

Research Questions

1. How were the students taught physical science in High School?
2. What difficulties have learners faced in the learning of physical science at high school?
3. What were the learners’ suggestions as the workable solutions to the difficulties faced?

Theoretical framework

Constructivism
The research anchored itself on the constructivist learning theory. According to the constructivist leaning theory Learning is an active process in which learners discover and construct new ideas or concepts based on their current and prior knowledge (Shahram, 2002)

One of the principles of the constructivists is that Instruction must be concerned with the experiences and contexts that make the student willing and able to learn.

Learners should take primary responsibility for their learning and own the process as far as possible (Wilson 2005).

Modern trends in teaching physics and teacher characteristics
Teaching in general has shifted from the traditional demonstration and showing method to a more hands-on approach as advocated by the SMASSE project (2003). Integration of traditional demonstrations with other methods when teaching sciences should also be encouraged because not all areas in physics can be taught through activities. One problem with conventional method of teaching physics lies in the presentation of materials (Mazur et al 2006). Only exceptional teachers can hold the students’ interest for a long time with traditional methods without actively involving them. Retention of materials learned is clearly because of active participation by the learner and close association with the learning materials. This is the reason why Sneddon et.al. (2009) say practical work forms a key component of teaching physics both at secondary and college level. Peer instruction, which involves learners sharing what they understood on concepts, is another instructional method advocated by Mazur et al (2006).

Reasons learners avoid studying Physics
From a study by Bevins, Brodie and Brodie (2005 in the United Kingdom (UK), students preferred Biology than Physics as it is less complex rather than Physics which requires learning difficult equations and laws. From the same study, learners also suggested that Physics is not as meaningful as Biology because they do not see its application in everyday life. Learners suggested more media coverage on the importance and the influence of science in society. Teachers could contribute to the failure by not bringing out the relevance of science. Musasia, Abacha and Biyoyo, (2012), say that the
low enrollment in upper secondary school physics is linked to a shortage of inspirational and well-trained physics teachers. They continued to argue that science teachers are mainly trained in theoretical content aspects.

**Students Difficulties in physics**

Physics requires the ability to use algebra and geometry and to go from the specific to the general and back. This makes learning physics particularly difficult for many students, (Redish, 1994). Lyons (2005) in a study in Australia revealed that for many students, physics is a subject that is perceived to be difficult and that should be dropped as fast as possible. In Nigeria, Erinosho (2013) said the students indicated difficulty in solving problems, doing calculations and constructing meaning.

**METHODOLOGY**

The study employed a descriptive research design which is ideal for gathering data from describing certain perceptions, opinions, attitudes, relationships and orientations held by a population (Tichapondwa, 2013). Purposive sampling was used to select 58 (35 females and 23 males) form 5 (High School final year) learners. The learners were selected from 6 randomly selected High schools in the Manzini Region of Swaziland. A structured open-ended interview guide with open-ended questions was used to collect data from the participants face to face. The responses were audio recorded and transcribed by the researcher and then given to colleagues to verify whether correct information would have been captured.

**DATA PRESENTATION, ANALYSIS AND DISCUSSION**

**Question 1** Learners revealed that most teachers used the lecture method and then provided notes for learners to copy. The students also indicated other methods such as practical work, class discussions, assignments and research work although these were used sparingly.

**Question 2** The difficulties faced by the learners were grouped under the following categories: difficulties from the nature of the subject, teacher, school and the learner himself/herself. The learners revealed that the language used in physics was different from the language used daily at home. The learners also had difficulties in doing the calculations and explaining the theoretical concepts. They proceeded to reveal that some of the teachers did not have adequate confidence and knowledge to teach certain concepts hence resorted to the textbooks and giving notes to the learners. There is need for teachers to have in-service training or workshops to help them deliver the concepts convincingly to the learners. Some schools lacked adequate laboratory material also reference material for the learners to consult in cases of difficulties.

**Question 3** the learners suggested the following workable solutions to their challenges:

a. Teachers were to create interesting lessons through the use of multimedia such as showing pictures, video clips and scientific movies. This was supported by Marusic and Slisko (2014),
who indicated that using technology in teaching often acts as a useful method for improving students' interest.

b. There was need to equip the laboratories for the learners to be able to do practical work including experiments for them to consolidate the understanding of the theoretical concepts.

c. The learners suggested that class and group discussions should always be utilized for the learners to learn from each other.

d. There was also need for teachers to provide extra tuition as much as possible especially during holidays and also provide exercises through assignments, homework and research work.

**Conclusion and Recommendation**

The conclusions drawn from the study were that teachers used the lecture method for instruction mostly and also read directly from the text books giving little or no examples of the concepts taught. In-service workshops should be held for both subject matter and teaching strategies to help the teachers. Less time was given to the learners for them to understand the physics concepts, as teachers tended to rush to complete the syllabus without much explanation given to the language of physics. Teachers were to use different strategies to assist the learners. Most schools lacked some laboratory equipment and tools hence practical work was rarely done hence most of the learners lacked experience in carrying individual experiments in preparation for the practical examination. All these experiences contributed to the lack of interest in Physics by most learners.

**References:**


Flanders, N.A., (1965) Teacher influence in pupils’ attitude and achievement. Co-operative research monograph No. 12, Washington


LEARNING TO TEACH BY PLANNING TO TEACH: Is Quality of Teacher Knowledge Compromised?
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Abstract
This study explored the relationship between the physical science pre-service teachers’ nature of topic specific pedagogical content knowledge (tsPCK) acquired in planning and that enacted in the classroom teaching of stoichiometry. The research study was based on the construct of tsPCK developed by Mavhunga (2012) as it focused on the knowledge required for transforming the content knowledge of a specific science topic. The study was performed on three groups of fourth year pre-service teachers doing a physical science methodology course at a university in South Africa. The participants were 12 in total. The data collected included the lesson plans, video-recording of microteaching and reflection reports all done by the participant pre-service teachers in the stoichiometry. The research used an in-depth qualitative method to analyse the results by looking for possible moments of integration of tsPCK components represented by tsPCK maps. The validated tsPCK rubric was used to quantify the observed tsPCK episodes and describe the quality of tsPCK. The data analysis revealed that even though there was a relationship in terms of components in the lesson plans and enacted lesson, the enacted lessons had a better quality than the lesson plans. It was also observed that most of the enacted lessons were interwoven and had more knowledge components of tsPCK than the lesson plans. The implications of the study were discussed.

1.1 Introduction

Lesson planning is a vital element in teaching and it goes beyond mere production of lesson plans. This is a view supported by Shulman (1987) who adds that planning for a lesson evokes a process of pedagogical reasoning. The process begins with comprehension; whereby a teacher is expected to understand what they are teaching. Shulman (1987) argued that, in doing so, the teacher is transforming the knowledge that they possess into forms that are pedagogically powerful. It is not adequate for a teacher to understand knowledge in one way. They need to understand it in many ways so as to offer alternative explanations, should students find one approach difficult (Bishop & Denley, 2007). Shulman (1987) adds that the transformation is a key element of Pedagogical Content Knowledge (PCK) as it facilitates learner understanding. Thus, a teacher who is able to generate explanations of difficult and abstract concepts in ways that learners can understand, despite their diversity, is said to have a good quality of PCK.
This study explores PCK as the teachers’ professional knowledge for teaching science topics. The science education community regards PCK as the professional knowledge for teaching science (Karal & Alev, 2016). There is a general agreement that learning to transform content knowledge is a central element of PCK that should be passed on to prospective teachers (Mavhunga, 2016). There is also an agreement that the value of teaching PCK to pre-service teachers lies in demonstrating and teaching PCK within a discipline’s topics (Abell, 2007). Exploration of the possible practical ways for implementing PCK within specific topics in science education was introduced by Mavhunga and Rollnick (2013). The authors reconceptualised PCK in a specific topic as a valid theoretical construct termed Topic Specific Pedagogical content knowledge (TSPCK). TSPCK refers to the understanding and the competence to pedagogically transform concepts in a specific topic using the content specific components of the construct in multiples and interactively (Mavhunga and Rollnick, 2013).

Little is also known at present about whether there is an empirical evidence pointing to the nature of the relationship between the quality of planned TSPCK vs. enacted TSPCK. This is the gap in the literature that this study is aiming to contribute towards. The study is nested in the specific topic of stoichiometry because the topic is perceived to be difficult to teach. For example, Bridges (2015) argues, based on a study on stoichiometry, that many students have problems learning stoichiometry due to teachers’ lack of understanding of how to teach the topic. Solving stoichiometric problems requires more than mere calculations. It involves the stringing together of many steps using conceptually organized knowledge (Ayoade, 2012); something that has been shown to pose difficulty to many students.

**Theoretical Framework**

After the work of Shulman (1986); Bishop and Denley (2007); Nilsson (2008) and many other researchers, it became apparent that there were too many conflicting ideas on PCK. Therefore, to reach a level of consensus, a group of researchers met in 2012 and created an agreed model; referred to Teacher Professional Knowledge (Consensus PCK Model) (Gess-Newsome, 2015, p31). This model is novel in that PCK is defined as both a knowledge base used in planning for and the delivery of topic-specific instruction in a very specific classroom context, and as a skill when involved in the act of teaching (Gess-Newsome, 2015). The consensus PCK model has been further refined to reflect the multidimensional nature of PCK (Carlson & Daehler, 2017). The new Refined Consensus Model (RCM) of PCK introduces three major realms of PCK: collective PCK (cPCK); personal PCK (pPCK); and enacted PCK (ePCK). The model describes the complex layers of knowledge and experiences that shape and inform teachers’ practice throughout their professional journey and, in turn, mediates student outcomes. A key feature of this model is the identification of three distinct realms of PCK: collective PCK (cPCK), personal PCK (pPCK), and enacted PCK (ePCK). Mavhunga and Rollnick (2013) drew their argument for tsPCK based on the process of transformation of content knowledge previously presented by Geddis and Wood (1997). Geddis and Wood (1997) attested that transformation of content knowledge emerges from the considerations of several different types of knowledge which are content specific. The resulting effect of such a consideration is that difficult
concepts in a topic are transformed into versions that could be understood by learners. The different kinds of knowledge that enables such transformation were listed as learner prior knowledge; curricular saliency, what is difficult to understand, representations and conceptual teaching strategies. According to Mavhunga and Rollnick (2013) the interest of the tsPCK model lies in developing teacher knowledge that may influence teaching practices within topics. This means that this model can be used to develop teachers’ teaching practices in classroom. The result of teachers knowing and reasoning their knowledge of a given topic through the five knowledge components is the transformation of their understanding into arrangements suitable for understanding by learners (Mavhunga & Rollnick, 2013).

Methodology

This study was based on an in-depth qualitative research design, with a total of twelve fourth year B. Ed students (pre-service teachers) who major in physical sciences considered as a particular case to study. The participants formed four groups and taught the lesson as a group. The groups worked closely with each other during the whole year and were never changed or separated. The preservice teachers were exposed to a six-weeks intervention on developing TSPCK in Stoichiometry. The intervention exposed the pre-service teachers to explicit discussions on the transformation of content knowledge of stoichiometry using the five knowledge components of TSPCK. The teachers voluntarily agreed to plan lessons under the stoichiometry topic and to teach that topic to their colleagues and that was regarded as microteaching. Data collected were primarily video-recorded lessons from each pre-service teachers’ group together with their lesson plans. The analysis of videos and lesson plans used a qualitative in-depth analysis method for episode of TSPCK (Park & Chen, 2012). The identified episodes for each participant were subjected to a criterion-based rubric (Miherso, 2017) that captures the classroom teaching TSPCK profile for each participant.

Findings and conclusion

The current preliminary analysis of data revealed that planning is not always congruent with the actual teaching however even though it is not in congruency the intentions in the lesson plans are seen in the actual teaching, some of the intentions in the lesson plan are scattered or interacting in a linear way and when they come out in enacted lesson they are clustered and interwoven. This study showed that planning a lesson does not mean that it will always come out exactly as it is in the enacted lesson. As Ling and Marton (2011) said that “The intended lesson plan may not be the same as the enacted lesson due complex and dynamic nature of classroom interactions. Sometimes the lesson can be disturbed by the way the learners are interacting with the teacher, learners may not respond to the teacher or they may be noisy and playful in a way that teacher may not teach what he intended to teach from his lesson planning. The study indicated however that it is always important to plan for the lesson because it helps to provide direction on how to teach and to prepare for the lesson better such as having the right experiment to help learners understand a certain topic better.
References


POSSIBILITY OF BIO ETHANOL GENERATION FROM TUBER’S WASTE: A COMPARATIVE STUDY OF CASSAVA AND SWEET POTATO

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ABSTRACT

Entitled "Possibility of Bio ethanol Generation from Waste of Tubers: A Comparative Study of Cassava and Sweet Potato", the research aimed to discuss and evaluate techniques for reuse of the waste of these tubers as raw material for the generation of clean energy in Manhiça District (Chafutene). The experimental work opted for non-probabilistic sampling. The collected tubers were washed, debarked, pre-grinded (60°C). The starch content was then determined by the Lane-Eynon method. The acid hydrolysis process, the relationship between the sugar content (°Brix), the hydrolysis time, the fermentation yield, were evaluated. This study was carried out in the period from May to November 2017. The final results showed that °Brix is a direct function of ethanol yield, pH, oxidation level and alcohol alcohol content of the starch concentration present in the tubers and the hydrolysis time of Cassava. and Sweet potato was 180h and 150h of sweet potato to reach 20°Brix respectively. The yield of the cassava fermentation process was 60% and that of potato 75%. This showed that sweet potato is the best raw materials for Bio ethanol generation, when compared to bitter cassava.

Key words: Sweet Potato, Cassava and Sweet potato Hydrolyzate, Renewable Energy, Bio ethanol.

INTRODUCTION

According to Silva (2013), the challenge of changing the energy sources that move the world economy, where oil and natural gas represent more than 50% of the world’s energy matrix, and only 13% of these are from renewable sources (hydroelectricity, wind and solar energy) has become a global necessity since the beginning of the Industrial Revolution.

Bio-ethanol produced from Biomass is recognized worldwide as one of the viable solutions for mitigating environmental pollution problems because it is less polluting and renewable (Lima, 2001).

Therefore, in a context where a majority of the Mozambican rural population (80%) do not have access to conventional electricity and dedicates themselves to agriculture producing and wasting important crops as a raw material for the production of locally useful clean energy, this study shows is relevant because it proposes the reuse of sweet potato and cassava waste for energy purposes.
According to Boane (2018) biomass is understood as the solar energy converted into chemical energy and stored in chemical bonds of organic compounds in plants and other types of residues, which can be transformed into solid bio fuels (firewood and coal), gaseous (Biogas) or liquids (Bio ethanol and Bio diesel),

**Bio ethanol study**
Bio ethanol is a liquid bio fuel produced from biomass or from the biodegradable fraction of sugary organic waste and is commonly used as industrial bio fuel and residential lighting

**Chemical characterization of Bio ethanol**
According to Lima (2001) & Goldmberg & Lucon (2006), Ethanol (C2H5OH), also called Ethyl Alcohol and in plain language alcohol, is a colorless and flammable liquid with a boiling point of 78.4°C, melting point of -114.3°C and a density of 0.79g/cm³. Ethanol is used in alcoholic beverages, solvents, perfumes, flavorings, paints, medicines, chemical compounds and thermometers.

**Bio ethanol production raw materials**
According to Silva (2013) Bio ethanol can be produced from raw materials containing starch or sugars (corn, wheat and other grains).

![Figure: Raw material used in the production of Bio ethanol](image)

**OBJECTIVES**

**General**
To Evaluate the possibility of generating Bio ethanol from Cassava and Sweet Potatoes for energy purposes.

**Specific**
To determine the time of hydrolysis of cassava and sweet potatoes according to the sugar content;
To relate the content of sugar and the establishment of the starch present in the hydrolysates of Cassava and Sweet Potato;
To compare the yield of Bio ethanol obtained by fermentation of Cassava and Sweet Potato.

**METHODOLOGY**
The present research of experimental nature, was based on a quantitative approach. According to Marconi & Lakatos (2003), the main objective of the experimental method is to test hypotheses that relate to cause-effect relationships.

The samples collected in Manhiça were stored in Polyethylene plastic during 15 days on the basis of the standards (ABNT 10007).

For the determination of Starch content, heat-catalyzed acid hydrolysis was used by mixing 2g of the sample, 100 ml of distilled water, 3 ml of 10% Hydrochloric Acid and 10% NaOH, heated for 60 minutes under constant stirring. (Goncalves et al., 2009).

The processed sugars were mixed with 10mL of the Fehling A solution, 10mL Fehling B, 40mL distilled water and the boiling 1% methylene-blue-indicator until reaching the titration endpoint (Goncalves et al. 2009).

For analysis of the sugar content (° Brix), 3mL of concentrated H2SO4, 200mL of distilled water, 5g of cassava flour and sweet potato were mixed and heated at 150°C for 180 minutes under constant stirring for 1 hour removed (Lane-Enon Method).

To determine the hydrolysis time, 3ml H2SO4 (conc.), 200ml distilled water, 5g Cassava flour and Sweet potato were introduced at 150°C for 30 minutes. Brix with refractometer.

After obtaining Bio ethanol, some physical-chemical properties were tested: combustibility, pH, alcohol content, appearance and primary oxidation.

a) Combustibility by the direct combustion technique.

b) pH - using pH meter HI 1270

c) Oxidation of primary alcohol - reaction with 10% K2Cr2O7 (m/v) in acidic medium (H2SO4).

d) Color and appearance - using spectroscopic (visual) and nephelometric methods.

e) Electrostatic content (%) - using spectroscopy in UV-Vis by reading the absorbance.

RESULTS AND DISCUSSION

The results obtained in the three tests showed that the Bitter cassava has a starch content of 73.4% and 82.56% for Sweet Potato, due to the fact that each of the cultures has its peculiarities. Goldmberg & Lucon (2006), is the most affected component, due to the diversity of climate, planting season, cropping system and timing.

Regarding the sugar content, the results are presented in the table below:
Table 1: Sugar content in Bitter Cassava and Sweet Potatoes

<table>
<thead>
<tr>
<th>Tubers</th>
<th>0 min</th>
<th>60 min</th>
<th>120 min</th>
<th>180min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bitter Cassava</td>
<td>2 °Brix</td>
<td>6,5 °Brix</td>
<td>12 °Brix</td>
<td>20°Brix</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>4 °Brix</td>
<td>8,0 °Brix</td>
<td>17 °Brix</td>
<td>28°Brix</td>
</tr>
</tbody>
</table>

The results in the table show that Sweet Potato had a higher content of Starch (28°Brix = 82.56%) in relation to Cassava (20°Brix = 73.4%), implying that there were more sweet potato Glucose formed in the degradation in relation to cassava. (Campelo, 2010).

The time spent for the hydrolysis of the biomass was 3 hours for bitter cassava and 2h: 30min for sweet potato to obtain the same yield, which is derived from the presence of fermentative yeasts and some micro-nutrients such as: Sulfur, Potassium, Zinc, Manganese, Copper, Iron, Cobalt, Iodine that catalyze the fermentation resulting in the lowest / highest consumption of sugars by the yeast during the fermentation process significantly lower yield in Cassava. (Campelo, 2008 & Lima et al., 2001).

Results of the physico-chemical analysis of Bio ethanol

In order to assess the quality of Bio ethanol produced, its properties were tested, taking as a comparative basis the Fuel Quality Standards described in the Regulation of the National Petroleum Institute approved in 2011 in Mozambique. The physicochemical properties tested are described below.

- **Combustibility**
  The Bio ethanol obtained from the two biomasses is flammable, burning with blue flame. In relation to the acidity test, the results showed that the Bio ethanol of Cassava was more acidic (pH = 6.44) and that of the Sweet potato were slightly alkaline (7.06), values considered accepted by the INP 2011 Regulation.

- **Oxidation of primary alcohol**
  The oxidation test with K2Cr2O7 revealed a greenish coloration at the bottom of the tube, showing that Bio ethanol was oxidized to Acetic Acid, (Feltre, 2004). as shown in equation below:

\[
3\text{CH}_3\text{CH}_2\text{OH} + 2\text{K}_2\text{Cr}_2\text{O}_7 + 8\text{H}_2\text{SO}_4 \rightarrow 3\text{CH}_3\text{COOH} + 2\text{Cr}_2(\text{SO}_4)_3 + 2\text{K}_2\text{SO}_4 + 11\text{H}_2\text{O}
\]

Regarding to the sensorial analysis, it was found that the Bio ethanol obtained was free of impurities and was colorless, satisfying the rules of the INP 2011 Regulation.

The alcoholic content of cassava was 76.01%, hydration level (24.99%), resulting from lower sugar consumption during fermentation, while sweet potato biomass had higher alcohol content (82.03%) and less than hydration (17.97%).
CONCLUSION

Sweet potato is the best raw material for the generation of bio ethanol in relation to bitter cassava. The bio ethanol obtained is within the standards recommended by the Regulation of the National Institute of Petroleum, and can be used as fuel in the residences.

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Abstract

The aim of this study was to explore how the integration of indigenous knowledge (IK) in the lesson of acids and bases influences (or not) learners’ conceptions and dispositions towards learning science. It was a qualitative study underpinned by the interpretive paradigm. Data were generated from seven learners’ journal reflections and semi-structured interviews with four learners. A thematic analysis approach was used to analyse the data. The study found out that integration of IK in the lessons changed the way the learners learnt science. It also enabled them to make sense of the concepts learnt. In addition, learners enjoyed using the familiar materials when learning science. This study thus recommends that teachers should strive to integrate IK where possible in their science lessons.

Keywords: Acids and bases, scientific knowledge, indigenous knowledge, conceptions, dispositions, sociocultural theory

Background and Purpose of Study:

The study aimed at exploring how the integration of IK in the lessons on acids and bases influences (or not) the learners’ conceptions and dispositions. According to Attalah, Bryant and Dada (2010), conceptions are views that learners hold about the subject and what they believe is required in learning or doing the subject. On the other hand, dispositions are the traits or characteristics that lead a person to follow certain choices or experiences (Damon, 2005). Learners’ conceptions and dispositions play a role towards learning the subject. Positive disposition, for instance, can influence the performance of the learners (Anwer, Igbal & Harrison, 2012). Hence, Gresalfi and Cobb (2006) emphasise that disposition can be influenced by connection between curriculum and home environment. It was thus anticipated that integrating learners’ socio-cultural context in the classroom would enable them to make sense of the concepts learned. The study thus sought to answer the following research question:

How does the integration of IK in lessons on acids and bases influence (or not) the conceptions and dispositions of learners toward science learning?

Literature Review and Theoretical Framework:
According to Le Grange (2007), integrating indigenous knowledge (IK) consolidates the connection between school science and learners’ everyday experiences (prior knowledge). Using learners’ everyday experiences in the lesson enables learners to participate actively in science lessons (Sedlacek & Sedova, 2017). That is, participation is enhanced when there is the connection between the everyday activities and science that is learned in the classroom. It also contextualises science so that the learners do not feel the foreignness of science (Aikenhead & Jegede, 1999). Learners are also afforded an opportunity to socially interact since the materials that are being used in the classroom are familiar to them.

This case study is thus informed by Vygotsky’s (1978) sociocultural theory. This theory emphasises that learning takes place during social interactions. It further states that human activities take place in a cultural context and these activities are mediated by language and other symbols. Concurring, Mavuru and Ramnarain (2017) posit that it is important to take into consideration learners’ socio-cultural background during science lessons. In the context of this study, use of easily accessible resources enabled the social interactions amongst the learners.

**Sampling:**

According to Bertram and Christiansen (2015), sampling is about selecting the people, setting or behaviour that have to be included in the study. In this study, purposive sampling was used since it focused only on those learners who did not perform well in Grade 9, and who were all placed in Grade 10B. An informed consent was obtained from the parents of these learners and they voluntarily participated in the study. Informed consent is obtained to assure that the researcher does not engage the participants who are unable to make decision due to immaturity or some sort of impairment (Cohen, Manion & Marrison, 2018).

**Research design and methods:**

This study is underpinned by an interpretive paradigm. According to Cohen, et al. (2018), an interpretive paradigm views the social world as an emergent social process which is created by the individuals concerned through experiences. Creswell (2014) explains that an interpretivist believes that individuals seek understanding of the world they live and work in. It is through social interactions that people construct meaning and make sense based on their historical and cultural perspective (Crotty, 1998; Vygotsky, 1978). Creswell (2014) further states that in the interpretive paradigm the research relies on the participants’ views of the situation being studied. That is, participants share their experiences in order to understand their values, beliefs and meaning of their social phenomena (Hussain, Elyas & Nasseef, 2013). Within the interpretive paradigm, a qualitative case study approach was used. Data were generated from seven learners’ journal reflections and semi-structured interviews with four learners. A thematic analysis approach was used to analyse the data to come up with themes in relation to the research question.
Findings and discussions:

The findings of this study revealed that the use of easily accessible resources familiar to learners enabled them to enjoy learning science. Additionally, they were able to understand scientific concepts on acids and bases. These findings resonate with Asheela’s (2017) study that easily accessible resources are useful in contextualising science. In addition, learners were also able to make connections between their everyday experiences with what they learned in the classroom. That is, they were able to link science to their real life. Roschelle (1995) explains that learning mostly starts from the prior knowledge and then later learners learn from the presented materials. Furthermore, teaching should start with the thoughts that are familiar to the learners.

Learners acknowledged that, they were not aware that from their environment they could find acids and bases that could be used to learn this topic. For this reason, Mukwambo, Ngcoza and Chikunda (2014) emphasise that we need to use local materials and Africanise the context so that science can be relevant to learners. Aikenhead and Jegede (1999) also argue that using the materials that are familiar to the learners contextualises science and learners do not feel the foreignness of science. This helps the learners to move between their everyday life and school science (border crossing) and how they can manage the conflicts that might arise between these two worlds.

Conclusion and recommendation:

It appeared that the integration of IK in the lessons shifted learners’ dispositions towards learning of acids and bases. It helped them to be able to learn this topic better because they were using materials that they are familiar with. This study thus recommends that for the learners to make sense of the science taught in the classroom, teachers should integrate everyday materials in their teaching. Learners seem to learn better when easily accessible resources are used. Easily accessible resources also enable border crossing from home to school science as reiterated by Aikenhead and Jegede (1999).

References


EXPLORING A BAT GAME AS A PEDAGOGICAL APPROACH TO ENABLE GRADE 7 NATURAL SCIENCE LEARNERS TO UNDERSTAND THE CONCEPT OF SOUND

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Abstract

Background

The study aimed at exploring the use of the traditional bat game with a view to enhance learners’ understanding of the concept of sound. This game is played in the evenings and learners (both girls and boys) have to stand in rows and swing sticks side-to-side at high speed in order to hit bats. Kibirige and Van Rooyen (2006) consider IK as a form of ‘traditional wisdom’ that is the product of practical engagement with the environment in everyday life. Notwithstanding, IK is not straightforwardly shared with members of other communities because of the elements which circulate within cultural communities. This game was intended to enable learners to understand that the notion of their everyday context can be of value in understanding scientific knowledge. Even though, fairy tales still exist as bedtime stories, but folk tales are beginning to be regarded even as some forms of ‘taboo’ by some people because they think it is only for uneducated and archaic village folks (Oring, 1989). A further argument is that folk tales reflect the moral value of a particular culture and society. Yet, to Oring (1989) folk tales have strong messages of ethics and values because they are with lucid and simple explanations that can simply used to improve the learners’ abilities towards understanding of science concepts.

Literature and theory

This study was inspired by a quest to explore the effectiveness of a bat game as the pedagogical approach to improve grade 7 learners’ understanding of the concept of sound. The study was informed by the socio-cultural theory of Vygotsky (1978). The socio-cultural theory emphasizes the important role of culture and context in constructing knowledge and enhancing meaningful learning. Additionally, Ogunniyi’s (2007a) Contiguity Argumentation Theory (CAT) was used as an analytical framework of the study. CAT assisted us to determine how learners made meaning after they had been involved in the bat game. Participation in the context of our study is situated in a social learning context (Mavuru & Ramnarain, 2017, Vygotsky, 1978). That is, learners were engaged in collaborative learning through game in a small group. The game was intended to act as a vehicle to provide an opportunity for learners to learn from each other and gain a better grasp of the subject – concepts to develop the necessary knowledge and skills to meet the learning competences. The participation in this game signifies social participation something which resonates with the social constructivist theory (Jung, Choi, Lim, & Leem, 2002; Vygotsky, 1978).
Purpose
The purpose of this study was to explore the use of a bat game to enable learners to cross borders from their everyday lived-experiences (context) to scientific knowledge (content). Learners experience about playing the game of bat in relation to sound and its phenomena. In actual fact, learners are able to reflect, think and act on situations they come across through the process of learning. Similarly, learners’ cultural beliefs about bats were explored using Vygotsky’s (1978) socio-cultural theory.

Sample
A purposive sampling was used to choose the grade, because the main study of the concepts of sound starts in primary Grades. For that reason, a Grade 7 class that consisted of 26 learners (16 boys and 10 girls) was chosen. All these learners gave informed consent to participate in the study. Creswell (2017) urged that researchers should be mindful of ethics by considering the nature of study, research questions, participants, context and the entire research process. In the end, ethics entailed informed consent, anonymity as well as confidentiality.

Research design and methods
The study is informed by the interpretive paradigm which entails understanding the subjective world of human experience and the efforts made to get inside the person and understand from within (Cohen, Manion & Morrison, 2011). Additionally, Ogunniyi’s (2007a) Contiguity Argumentative Theory (CAT) and Vygotsky (1978) Socio-cultural theory were used as an analytical tool. That is, the five constructs within this theory, namely, dominant, suppressed, assimilated, emergent and equipollent enabled the data analysis process. A thematic and inductive approach to data analysis was adopted.

Results
From the focus group interviews conducted before the bat game, all learners reported that they had no or little knowledge of why bats are so difficult to be hit by a swung stick. After engaging learners in the bat game, they were able to explain the uses of echo, which is an everyday experience. For instance, learners explained that the stick is what reflects the sound, not the bat. As a result, the bat was able to avoid being hit by the sticks. Evidently, after learners engaged in game bat showed more understanding of the concept of sound. Contextualizing science teaching involves the use of learners’ everyday experiences as machinery for conceptual attainment (Otero & Nathan, 2008). Learners had an opportunity to share their experiences of not hitting bats by swinging stick(s) during the time of the game.

Conclusions and recommendation
It emerged from this study that on contextualizing science teaching involves the use of learners’ everyday experiences as machinery for conceptual attainment (Otero & Nathan, 2008). Equally, science teachers should consider providing sufficiently inviting learning environment in which learners can make meaning. The study thus recommends that educational reforms and teaching strategies in Namibia should persuade teachers to accommodate learners’ cultural norms, values and beliefs.
through games in the context of the study as learners’ everyday knowledge when teaching natural science. In fact, the bat game is played outside the classroom, which is an out-of-school context (Mavhunga & Kibirige, 2018).

**Keywords**: Folklore, Indigenous Knowledge, Bat Game, Sound, Socio-Cultural Theory, CAT

**References**:


LEARNING THE TOPIC ON WAVES THROUGH THE INTEGRATION OF INDIGENOUS KNOWLEDGE

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Abstract

The new South African National Curriculum Policy Statement (CAPS) clearly states that local or indigenous knowledge (IK) should be integrated in science lessons to make it accessible and relevant to learners. But it does not state how this should be done. It is against this background that in this study we aimed at exploring the influence of integrating local or IK when teaching the topic on waves on learners’ conceptions and dispositions towards science. Underpinned by an interpretivist perspective and informed Vygotsky’s socio-cultural theory, a qualitative case study approach was employed. Data were generated using observations and learners’ reflections. A thematic approach to data analysis was adopted. The findings of the study revealed that learners’ conceptions and dispositions were positively influenced by integrating IK in the topic on waves. The study thus recommends that there is a need, where possible, for science teachers to integrate IK in their science lessons.

Keywords: Physical Sciences, waves, local or indigenous knowledge, conceptions, dispositions, socio-cultural theory

Background and Purpose of Study

Nyika (2017) understands IK as knowledge that is unique to a society. Hence, in this study a community member who according to Vygotsky (1978) is regarded as the more knowledgeable other, was invited to share his experiences and knowledge about the sea, in particular, the cultural beliefs associated with the sea and the waves. This is in line with one of the general aims of the new curriculum of South African (valuing indigenous knowledge), commonly known as Curriculum and Assessment Policy Statement (CAPS, 2012). CAPS emphasize that there is a need to acknowledge the rich history and heritage of this country. In agreement, Cocks, Alexander and Dold (2012) reiterate that there is a need for cultural revitalization in South Africa. To Naidoo and Vithal (2014), recognition of the critical role of indigenous knowledge systems (IKS) in science in the new South African national curriculum for schools affirms the importance of IKS. Additionally, as Nyika (2017) posits that unlike Western science, which is learned passively in the classroom and/or laboratory, in contrast, IK is experiential.
The purpose of this study was thus to explore the influence of integrating local or IK when teaching the topic on waves on learners’ conceptions and dispositions towards science. Essentially, both the sea (out-of-school context) and IK were used as cultural tools to foster learning amongst the learners (Vygotsky, 1978). The study thus sought to answer the following research question:

**How does the integration of indigenous knowledge in the topic on waves influence (or not) grade 10 learners’ conceptions and dispositions?**

**Literature Review and Theoretical Framework:**

Botha (2010) emphasized that increasingly the benefits of epistemological diversity are being realized in countries such as South Africa, focusing on a more culturally diverse education to unlock this potential for development. Mavuru and Ramnarain (2017) emphasize the importance of taking into consideration learners’ diverse socio-cultural backgrounds in science classrooms. Similarly, Mahakure and Otulaja (2017) advocate for cultural responsive pedagogies. Partly, this study was inspired by these scholars’ insights, but largely by our quest to inspire and develop grade 10 learners’ interest in science. Furthermore, to ultimately improve their understanding of the concepts on waves. The study is informed by Vygotsky’s (1978) socio-cultural theory. Central to socio-cultural is that meaningful learning takes place in a social plane. Within this theory, social interactions and the Zone of Proximal Development (ZPD) were used for data analysis purposes.

**Research Design and Methods**

Bertram and Christiansen (2015) argue that a research paradigm represents a particular worldview that defines for the researcher who holds this view, what is acceptable to research and how this should be done. This study is located within an interpretive paradigm whose focus is on developing a greater understanding of how people make sense of contexts in which they live and work (Cohen, Manion & Morrison, 2018). Within the interpretive paradigm, a qualitative case study approach was employed. Additionally, Vygotsky’s (1978) socio-cultural theory which emphasizes the important role of culture and context in constructing knowledge was used as a theoretical framework. In terms of methodology, a community member working in the school grounds was invited to do a presentation at the sea on waves to a grade 10 science class. The presentation was video recorded. Data were thus generated through observations and learners’ reflections.

**Sample**

A grade 10 class was purposively selected since the topic on waves is covered in this grade. The class consisted of 18 learners (with an equal number of girls and boys) who volunteered to be part of this study. In addition, permission was also sought from the learners’ parents involved in the study. A community member, who was working at the school’s grounds (65 years old) who accompanied the science teacher and the learners were generously willing to share his experience and local knowledge about the sea. The outing to the sea was intended to provide an out-of-school context for learning.
Thus, an outing to the sea was deemed relevant in the study, as it provided an avenue for exploring how learners’ dispositions towards science were influenced.

Findings and Discussions

The findings of this study revealed that the interactions between the learners and the community member were very informative. The community member shared some cultural beliefs, for example, he told them that there was a belief that if you are a twin or a twin’s younger brother, you had to pull hair from your head and throw it in the sea as a sign of respect for the ancestors, before you and your friends could swim and have some fun in the sea. He also explained that the earth was not flat by illustrating that the boat would sail from the shore and at some point, would disappear indicating that the earth was round. The learners related to some of the stories that were narrated by the old man, and they eagerly asked questions and also discussed amongst themselves suggesting that these were culturally relevant (Mhakure & Otulaja, 2017). The learners appeared to be enjoying the teaching approach, as they also reflected in their journals, using phrases such as: “I enjoyed the lesson very much”, and “more lessons like this would be nice”. To Carr and Claxton (2002), the fundamental purpose of education for the 21st century is to engage in lifelong learning.

Conclusions and Recommendations

It seems that the both the use of out-of-school context and the integration of IK in the topic on waves has had a positive influence on the learners’ conceptions and dispositions towards science. The level of learner participation (Sedlacek & Sedova, 2017; Vygotsky, 1978) during the teaching and learning and their reflections on their journals are an indication that there was a positive shift in the learners’ dispositions. It is recommended that a further research on the study be conducted. Additionally, the study recommends that science teachers should explore the possibility of integrating IK during their science lessons.

References:


MOBILIZING LOCAL KNOWLEDGE ON WOOD ASH TO TEACH THE CONCEPT OF NEUTRALISATION REACTIONS
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Abstract
The Namibian Grade 9 Physical Science curriculum expects teachers to integrate learners’ local or indigenous knowledge. But there are no clear instructions on how to go about doing this. It is against this background that this study aimed at mobilizing the use of wood ash to teach the topic of neutralization reactions in science classrooms. The indigenous practice of using wood ash is viewed as having a potential in enhancing learners’ sense-making of neutralization. The study is underpinned by an interpretive paradigm and is informed by Vygotsky’s socio-cultural theory and Wenger’s community of practice. Within the interpretive paradigm, a qualitative case study approach was employed. Data were gathered using document analysis, classroom observations and post lesson reflections. Data were subsequently analysed inductively to come up with themes. The findings of the study revealed that the use of wood ash enabled learners to make sense of neutralization reactions. The study thus recommends that teachers should integrate learners’ local or indigenous knowledge.

Keywords: Physical Science, neutralization reactions, indigenous knowledge, socio-cultural theory, CoP

Context and Purpose of Study
The Namibian Grade 9 Physical Science curriculum expects teachers to integrate learners’ local or indigenous knowledge. Furthermore, the Namibian National Programme on Research, Science, Technology and Innovation (2014 - 2017), prioritises indigenous knowledge (IK) as a critical area of research that can address Namibia’s social challenges. Despite these ideals, there are no clear instructions or support on how to go about integrating IK in science lessons. The purpose of this study was thus to explore an intervention on the integration of local or indigenous knowledge (IK) in Grade 9 Physical Science lessons. Essentially, the science teachers involved in this study contextualized their science lessons by using wood ash to demonstrate the concept of neutralization reactions. Culturally and locally, learners have prior knowledge on wood ash. As a result, they were able to carry out practical activities and make sense of neutralization reactions. The study thus sought to answer the following research question:

How do Grade 9 Physical Science teachers mediate learning of lessons which integrate local or indigenous knowledge (IK)?
Literature and Theoretical Framework

Emeagwali and Dei (2014) argue that there is a need to recognize local cultural ways of knowing as legitimate sources of knowledge. Concurring, Mukwambo, Ngcoza and Chikunda (2014) propose Africanisation of the science curriculum. Similarly, Mavuru and Ramnarain (2017) emphasize the importance of taking into consideration learners’ socio-cultural backgrounds. In his study, for instance, Mukwambo (2016) articulated that Contextualized Teaching and Learning Pedagogical Practices (CTLPP) bring a genuine context that helps the learners to see the relevance of science concepts that the teacher presents. These scholars believe that integration of local or IK in science lessons has a potential to contribute to the relevance and sensitivity of learners’ cultural context (Cocks, Alexander & Dold, 2012; Mhakure & Otulaja, 2017; Webb, 2013).

The study is thus informed by Vygotsky’ (1978) socio-cultural theory as well as Lave and Wenger’s (1991) Community of Practice (CoP). Socio-cultural theory describes learning as a social process and that social interactions play a fundamental role in the development of cognition (Vygotsky, 1978). Vygotsky (1978) believes that everything is learned on two levels, which is through interaction with others, and then is integrated into the individual’s mental structure. Similarly, the construct of CoP is grounded in socio-cultural theories of learning and development that Vygotsky (1978) and Engestrom (1987). Both these theories contend that all human development is founded upon social interactions in cultural and historical practices that are mediated by the use of cultural artifact, tools and sign. CoP thus informed the study based on how the group of individuals participated in a social set up within the community and shared their knowledge, experiences and learned from each other.

Research design and methods

This study is located within an interpretive paradigm. It is a qualitative, intervention case study. An interpretive paradigm was adopted in this study to grasp subjective meaning of the social world of the participants (Cohen, Manion & Morrison, 2018). That is, the interpretive paradigm aims at developing a greater understanding of how people make sense of the context in which they live or work, whereby the researcher engages the situation from their viewpoint (Bertram & Christiansen, 2015). Komorek and Kattmann’s (2009) Model of Educational Reconstruction (MER) for teacher education and Eun’s (2008) theoretical concepts within professional development were used as the analytical framework that guided data analysis. Within the interpretive paradigm, a qualitative case study approach was adopted. Data were gathered using document analysis, classroom observations and post lesson reflections. Data were analysed inductively in relation to the research question.

Sampling

A purposive sampling was employed whereby two grade 9 Physical science teachers from two Secondary Schools in Otjiwarongo circuit were selected based on their willingness and their local or IK knowledge for lesson presentation. Bertram and Christiansen (2015) define purposive sampling as a sampling method whereby the researcher chooses a specific sample for a particular purpose. The
first author and participants co-developed two model lessons that integrated local or indigenous knowledge. The model lessons were taught by each science teachers while the first author observed the lessons.

**Findings and Discussions**

The findings of this study revealed that teachers were able to mediate lessons that integrate local or IK. It emerged that wood ash was used to practically to neutralize fatty acids on the stove, microwave, dishes and other household utensils. From the teachers’ post-lesson reflections, it appeared that the integration of local or IK in Physical science lessons helped their learners to participate actively and were engaged in discussions (Sedlacek & Sedova, 2017). Furthermore, teachers were also able to develop Learning and Teaching Support Materials (LTSMs) that are locally and culturally grounded. This is what Mhakhure and Otulaja (2017) refer to as culturally responsive pedagogy.

**Conclusions and Recommendations**

The findings of this study revealed that the use of wood ash as a cleaning and neutralising agent was embraced by both teachers and the learners. It became evident that for learners to participate fully in the learning process, teachers need to apply Contextualized Teaching and Learning (CTL) pedagogies (Berns & Erickson, 2001). This study thus recommends that teachers need to understand how to integrate learners’ local or IK in their classrooms. Furthermore, future studies are urged to look at discovering some more indigenous practices that can be used to contextualise teaching and learning processes during science lessons.

**References**


HOW PRE-SERVICE TEACHERS COMMUNICATE SCIENCE CONCEPTS WITHIN THE TOPIC OF ELECTRICITY
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Abstract
Extensive research has been conducted on talk as a tool for communication of science concepts in science learning and teaching. Talk in science education has been advocated as a tool that can help students monitor their own scientific reasoning. This study aims to investigate how talk facilitates engagement with the key concepts of the topic of electricity in various learning environments such as lectures, laboratory work and tutorials in a pre-service teacher programme. The focus is on how pre-service teachers communicate scientific concepts among themselves and with the lecturer on the topic of electricity. The findings of such a study can illuminate the nature of student engagement with science concepts and how they communicate their understanding of the science as well as difficulties that students encounter in making sense of the topic of electricity. The findings could further inform teacher education on how to prepare pre-service teachers to teach this topic which many school learners find very difficult. Key words: science concepts, talk, electricity, pre-service teachers

Introduction
School science research has focused on classroom talk during small group class activities and during whole class discussions (e.g. Mortimer & Scott, 2003, Christodoulou & Osborne, 2014). However, little attention has been given to talk that occurs in science pre-service teacher programmes. Research has shown that science topics like electricity are difficult to teach and to learn. More specifically the challenge is on unpacking how electrons are involved in the transport and distribution of energy in the circuit (see for example Kucukozer & Kocakulah, 2007; Duit & von Rhoneck, 1997; Korganci, Mirona, Dafineia & Antohe, 2015). In addition, literature shows that pre-service teachers cannot explain electric current in terms of the flow of electrons around a circuit (Kucukozer & Demirci, 2008). Teaching and learning of electricity concepts need to be enhanced for students to understand the behaviour of electrons and charges at the microscopic level (e.g. Korganci, Mirona, Dafineia & Antohe, 2015). As such, talk could be a tool to give pre-service teachers the opportunity to verbalise their understanding and provide the opportunity to question the lecturer for articulation of understanding of the topic of electricity. It is important to establish pre-service teachers’ understanding of the topic of electricity as they in turn will have to teach it to school learners when they graduate.
Literature Review

This study adopts the sociocultural perspective to describe how individuals learn. Vygotsky (1978) argued that learning occurs through interactions and thus knowledge is co-constructed within the social interactions. Vygotsky (1934/2003) asserts that the nature of scientific concepts is characterized by the abstractness of the concepts that needs to be made explicit to learners.

Pre-service teacher learning is complex and has multiple factors which includes the purpose of learning, the why aspect, the characteristics of their prior beliefs, where their learning is taking place, what they are actually learning, what aspect, how learning occurs and the social context (Conklin, 2015). Learning is a process and how pre-service teachers learn is ‘includes the instructional practices that teacher educators use to facilitate this learning’ (Conklin, 2015, p. 327). How pre-service teachers actually learn is a critical process to understand for the purpose of this study. Thus, from the aspects highlighted by Conklin (2015) I will focus on their prior beliefs about talk and their prior knowledge of and beliefs about electricity, in three contexts lecture, lab or tut, and what evidence of their learning can be traced in their interactions.

This study is guided by the following main research question: What patterns of communication unfold as pre-service teachers engage in talk during lecture sessions, laboratories and in tutorial sessions within the topic of electricity? This study is guided by the following sub-research questions:

1. What patterns of interaction unfold as pre-service teachers and their lecturer talk in lectures within the topic of electricity?
2. What is the quality of pre-service teachers talk on the topic of electricity within their small groups in laboratory and tutorial session and
3. What evidence of learning can be gleaned from their talk?

Methodology

This study investigates talk by physical science pre-service teachers who are in their 3rd /4th year of the Bachelor of Education degree, majoring or sub-majoring in Physical Science. This is a case study focusing on a group of physics third/fourth year pre-service teachers. Case study research is an example of qualitative research. According to Merriam, “A qualitative case study is an intensive, holistic description and analysis of a single instance, phenomenon, or social unit” (Merriam, 1998, p. 27). The main method of collecting data will be observation of the lectures, laboratory and tutorial sessions. The interaction in all these three learning environments will be video and audio recorded.

Data analysis and interpretation

The video and audio recorded lessons will be transcribed as the first step towards the data analysis process. The analysis of the talk used in this study will be based on Mortimer and
Scott’s (2003) model for classroom interaction. This is a tool for analysing meaning making interactions in the classrooms. This framework will be used to explore how the talk is executed in meaningful learning of scientific concepts in electricity during the engagement between the lecturer and pre-service teachers. Communicative approaches and patterns of interactions are two of the basic aspects of talk that support meaningful learning of science knowledge according to (Mortimer & Scott, 2003). On the poster I will present preliminary data which I would have gathered in block four as my proposal has been accepted. I would like to get advice on the analytic framework that I am planning to adapt and where the findings are feasible.

References


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EXPLORING POSSIBILITIES FOR INCLUDING INDIGENOUS KNOWLEDGE IN SCIENCE TEACHER EDUCATION

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The current higher education landscape privileges epistemic traditions, which are rooted in western frameworks, especially in science education. Over time, this has resulted in devaluing the knowledge of non-western people. In an effort to develop a more inclusive science teacher education curriculum, I use a social justice theoretical approach to focus on how a science preservice teacher education module can be used to integrate indigenous knowledge. This is engaged with by disrupting and reframing who the legitimate knowledge holder in higher education is, and what constitutes valuable scientific knowledge. The research question which underpins this enquiry is: What are science preservice teachers’ views about engaging indigenous knowledge holders, and incorporating indigenous knowledge, in the science curriculum? Data for this qualitative study was generated from 50 preservice science teachers who developed food gardens in a project titled “Nutrition for Health”. These teachers completed questionnaires and developed portfolios of evidence. Data drawn from these sources were analysed thematically. Findings revealed that preservice teachers were successfully provoked into rethinking who teaches and what is taught in science education. They endorsed indigenous knowledge holders as legitimate teachers in higher education and exhibited a renewed enthusiasm for the application of indigenous knowledge to maintain healthy lifestyles.

Introduction

The South African higher education institutions (HEIs) rely heavily on Euro-western knowledge systems and knowledge holders. Connell (2016) states that the theories and methods advanced by these Euro-western nations are the standard used to measure excellence in higher education. The complicity of the HEIs in South Africa in valuing curriculum models, textbooks and theories, which are embedded in Euro-western epistemic frameworks, is undeniable (Heleta, 2016). The South African higher education terrain has been reverberating with calls for the remaking and democratisation of intellectual culture (Shay, 2016).

Literature review and theoretical framing

According to Hountonji (2009, p.9), education has been used as a vehicle to attain the goal of engaging in an “autonomous, self-reliant process of knowledge production” that “meet both the intellectual and material needs of African societies”. The transformation of curricula, which involves rendering them culturally inclusive, is key in reclaiming African cultural identity (ibid). Within the
South African context attempts have been made to recentre African knowledge by including IKS in the school curriculum. The attempts to re-centre African knowledge are evidenced in colossal shifts in the school curriculum (Department of Basic Education, 2011). The successful implementation of curriculum policy in this respect has been hindered by inadequate teacher training. In this presentation, ways in which preservice science teachers are taught to include IKS in their practice are revealed.

Le Grange (2016) draws on the work of Deleuze and Guattari (1994), Wallin (2010) and Pinar (2011) to understand the conceptualisation of curriculum. The space between curriculum as a plan and curriculum as lived can be utilised as an opportunity for curriculum change. Le Grange encourages conceptualising curriculum as a verb, as dynamic, as a space for creativity and expansion, unbounded by territory. “Ubuntu-currere”, which departs from the egocentric, separate “I” of western individualism towards an “I” that is integrated with humans and the “more-than-human-world” is argued for (Le Grange, 2016, p.9). Le Grange (2016, p.9) draws our attention to “an emergent Indigenous paradigm” which are based on the 4Rs. These are relational accountability, respectful representation, reciprocal appropriation and rights and regulations (ibid).

Methodology

This study was framed using a qualitative, case study approach. Fifty purposively selected preservice science teachers volunteered to participate in this study. These preservice teachers were registered for a Bachelor of Education degree and were studying a content module in Biology. The curriculum which informed the module activities was redesigned to include the role of IKS in maintaining health. Questionnaires which were based on these preservice teachers’ experiences of being taught ethnobotany by permaculture expert and an indigenous knowledge holder, were developed. The preservice teachers also developed gardens for health, and generated portfolios of evidence to provide details of their activities. Both the questionnaires and the portfolios of evidence were used as data sets.

Findings and conclusions

An exploration of the who of curriculum transformation revealed that the preservice teachers were impressed by the pedagogical strategies employed by the indigenous knowledge holder. They valued her as an authentic knower and teacher of valuable knowledge, unlike many higher education teachers, who, they said, simply read from powerpoint slides. They believed that she had deeper subject matter knowledge because she had constructed this knowledge through lived experience.

Preservice teachers also engaged in the what of curriculum transformation by researching indigenous plants, including Iboza and African ginger, and constructed knowledge about the active chemical ingredients which were linked to maintaining good health. They also believed that the low cost of producing indigenous crops for maintaining health was especially suitable for economically deprived
communities. Their views echoed those of Kiti (2013) who explained that self-reliance through appropriation of indigenous knowledge was relevant to African communities. Preservice teachers also became conscious of the epistemic violence which occurs when knowledge systems are subjugated.

This study revealed a departure from monoculture perspectives (Kincheloe, 2008) of higher education teachers and knowledge production. It revealed how preservice teachers can be stimulated to reawaken to new possibilities of what is valuable science and who can teach science in HEIs.

References


TRANSFERRING BIODIVERSITY KNOWLEDGE IN THE CLASSROOM

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Introduction

In recent years biodiversity has become topical not only to academics but to politicians, activists and the common individual because of its importance in sustaining livelihoods. According to the 2012 UN Rio+20 conference the impact of biodiversity loss to humanity undermines global development by affecting food security, provision and access of water and the health of the rural poor and of people worldwide. The causes of this rapid loss of biodiversity however vary from country to country. Biodiversity loss in Zimbabwe is due to inadequate alternatives for energy sources, poverty, deforestation, wetland degradation resulting from population growth, encroaching human settlements and selective harvesting of plant products (Government of Zimbabwe/UN, 2010).

Background of study and literature Review

An appropriate programme for biodiversity education has potential to reduce biodiversity loss (Kassas, 2003, Barker and Elliott, 2000, Gayford, 2000). Zimbabwe acknowledges this fact by including biodiversity concepts in biology and geography curricula at various levels. Teaching the concepts however reveals that the concept embraces both scientific and non-scientific aspects. The non-scientific or socio-scientific aspects of biodiversity are reinforced by the different experiences and practices in the learner’s context. It is desirable therefore that teachers create learning opportunities that enable learners to explore the various aspects of biodiversity knowledge. Some studies have shown that concepts that demonstrate scientific and non-scientific dimensions are successfully taught using argumentation. Hence, teachers in my study engaged argumentation to teach biodiversity aspects regarding the protection and management of biological diversity and its related environments.

The quality of an argument can be determined using Toulmin’s Argument Patten (TAP). TAP illustrates the structure of an argument in terms of claims which are assertions put forward publicly, data supporting the claim, warrant providing the link between claim and data, backings strengthening the warrants and rebuttals which are circumstances through which the claim would not hold true. However, this analysis is most appropriate for scientific argumentation and usually inadequate in analyzing arguments on socio-scientific issues (SSI). Groom et al (2014) found out that to support SSI related issues students used more ‘personal’ justifications in their arguments. In other words, distinguishing the knowledge used by students to make decisions is not clear cut. In fact, negotiating
complex issues often see students engage in sociocultural factors (Sandler and Zeidler 2005a) to explain phenomena. Socioscientific argumentation is often used to investigate issues in context particularly local environmental issues and healthy related issues. This involves proposing, supporting, critiquing and refining a claim. This paper explores how learners talk about biodiversity concepts in their different context and how they relate to the bigger biodiversity discourse. This paper responds to the question: How do learners engage with argumentation in transforming biodiversity knowledge in the classroom?

**Methodology**

The data was collected as part of my PHd study which is exploring the practices and experiences of beginning biology teachers. The beginner teachers are those that have just graduated from the Bachelor of Education (BEd) programme and are in their first and second year of teaching advanced levels. As part of the pedagogy course student teachers engaged in activities promoting the use of argumentation as a teaching strategy. The two lessons reported in this paper where selected from three argumentation lessons taught to an advanced level class as part of a practical session to assess the student teachers uptake of this new teaching strategy. The lessons were observed and video recorded. Activities took the form of whole class discussions and small groups as described in Braund et al (2007).

In the first lesson learners were provided with three handouts with different printed graphs and statistics showing the decline of the African elephant populations over several years. Learners were then asked to give reasons why the African Elephant should be conserved if they belonged to the community residing in the margins of Gonarezhou National Park known for its large populations of elephants in Zimbabwe. In the second lesson learners were provided with a statement outlining how fertilizer is used to increase production and how this destroys the ecosystem. Handouts with various photographs showing farms with crops, and forest areas cleared of vegetation in preparation for farming were provided. Learners were divided into two groups. One group were arguing in support of Production and the other in support of Conservation.

**Results and Discussion**

I am currently analysing the arguments using analytical tools adapted from Groom et al (2014) which review the level of argument structure and the nature of justifications.

**References**


 USING INQUIRY BASED APPROACH AS AN INSTRUCTIONAL METHOD TO DEVELOP SCIENTIFIC PROCESS SKILLS IN TWO ISIXHOSA FOUNDATION PHASE CLASSROOMS

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Abstract
This interpretive study used Socio-Cultural Theory and Principles of Inquiry Based approach as analytical lenses to understand how two Grade 3 Foundation Phase teachers made use of the learners’ home language (isiXhosa) as a language of instruction to implement scientific inquiry approach in their classrooms. Data were collected using questionnaires, semi-structured interviews as well as observations. A thematic approach to data analysis was adopted and Zaretsski’s six conditions in conjunction with the principles of inquiry approach were used as analytical lenses. Using the learners’ Home Language as an instructional tool, findings revealed that learners were afforded an opportunity to freely engage in activities. Although learning activities could be improved, teachers created social spaces for learners to take part in learning.

Keywords: Foundation Phase Teachers, Inquiry- Based Approach; Scientific Process Skills, Socio-Cultural Theory (SCT), Mediation and Zone of Proximal Development

Introduction

Some of the recent studies have looked at Foundation Phase (FP) teachers’ perspectives on the teaching of science in FP (Bosman, 2006; Beni, Stears & James, 2012; Banu, 2013; Koen & Ebrahim, 2013; Plaatjies 2015). These studies have highlighted various challenges on the teaching of science in the Foundation Phase. For instance, they highlighted issues of large class numbers, lack of resources and lack of science knowledge from Foundation Phase teachers. But none of these studies investigated how Foundation Phase teachers use scientific inquiry approach in their classrooms (Department of Education, 2011). Even though several challenges on teaching science both at secondary and primary level have been presented by many scholars, the argument is strongly made that elementary or Foundation Phase learners should be exposed in learning of science (Worth, 2010; Bosman, 2011; Beni et al., 2011; and Koen & Ebrahim 2013). Seemingly the use of learners’ everyday life experiences and their surroundings is important in developing their scientific knowledge and skills (Kuhlane, 2011). Therefore, at FP level teachers should not think of laboratory equipments or even formal experiments but see their learners as real scientists in action using whatever is available to solve problems at hand.
When teaching science in Foundation Phase; the Life Skills curriculum encourages teachers to develop scientific process skills in learners and to develop learners holistically (Curriculum Assessment Policy Statement, 2011). Eshach and Fried (2005) and Worth (2010) also suggest reasons why young learners should be taught science in their early years of schooling. They posit that young children naturally enjoy observing and thinking about nature; exposing learners to science develops positive attitudes towards science; the use of scientifically informed language at an early age influences the eventual development of scientific concepts; children can understand scientific concepts and reason scientifically; and science is an efficient means for developing scientific thinking.

The study was thus guided by the following research questions:

1) What is the understanding of Grade 3 FP teachers of inquiry-based approach and of scientific process skills?
2) How do Grade 3 teachers mediate the development scientific process skills through inquiry-based approach using learners’ mother tongue?

**Theoretical Framework**

This study is underpinned by Vygotsky’s (1978) socio-cultural theory. Vygotsky stated that humans do not act directly on the physical world but rely, instead on tools and labour activity which allow them to change the world. He further argued that symbolic tools or signs mediate and regulate the human relationships with each other and within themselves and thus change the nature of these relationships. Vygotsky (1978) recognised learning as both the cognitive and a social origin of mental development and learning. Rubtsov (2016) states that the most fundamental concept of socio-cultural theory is that a human mind is mediated. Vygotsky’s socio-cultural theory was based on the principles that mediation of learning through language and cultural tools, symbols and artifacts, social activity and cultural practice as a source of thinking (Moll, 1990). Thus, the concept of “Mediation” with regards to teachers developing their learners’ inquiry skills was the key in this study. Also, how teachers develop the learners’ ZPDs with regards to their understanding of the developed inquiry skills during the mediation process was also of importance in this study. Hence, Zaretskii’s six conditions in developing learners’ ZPDs during learning together with the principles of inquiry-based approach were used as analytical lenses in this study.

**Methodology**

The study sought to understand how Grade 3 FP teachers use inquiry approach in developing scientific process skills (CAPS, 2011). We deemed it appropriate for this study to be underpinned by an interpretive paradigm. Within the interpretive paradigm, a qualitative case study was employed (Bertram & Christiansen, 2015; Creswell, Ebersohn, Eloff, Ferreira, Ivanka, Jansen, Nieuwenhuis, Pietersen & Plano Clark and Cohen, Manion & Morrison, 2018). With reference to sampling, the study was conducted in two schools with two female IsiXhosa speaking teachers. Both schools were township schools, a quintile 3 and a quintile 4 school in the Sarah Baartman District in the Eastern
Cape. The learners in these schools were also IsiXhosa speakers; and in both classrooms there were 40 learners. Data were generated mainly from the questionnaires, semi-structured interviews and video recorded lessons. Data were subsequently analysed inductively to answer the research questions.

Findings and Discussions

It emerged from the findings that even though the teachers in this study understand the inquiry-based approach and have knowledge of scientific process skills they are still grappling with how they can effectively implement the approach and use it to promote scientific knowledge and develop the scientific process skills in their Grade 3 learners. Although this was not a comparative study, these teachers were at different ZPDs in terms of development of scientific process skills, and the implementation of inquiry-based approach (Stott, 2016). Also, the findings revealed the use of language of learners during teaching created a positive atmosphere for both learners and teachers (Mavuru & Ramnarain, 2017).

Conclusion Remarks and Recommendations

The study explored the use of scientific inquiry approach in developing scientific process skills through isiXhosa. The group activities, the use of familiar resources made it easier for learners to engage in learning activities (Kuhlane, 2011). On the other hand, this study revealed the need for Foundation Phase teachers need to be supported in strengthening their planning of inquiry-based lessons. This could be done in reference with the principles of inquiry approach and Zaretskii’s six conditions for development of learners’ ZPDs during learning. These are clearly evidence of educational implications in relation to equipping Foundation Phase teachers on the implementation of inquiry-based approaches to develop scientific process skills and scientific knowledge in their classrooms.

References


ABSTRACT
Providing effective science teaching today may depend in part on the teacher having a range of interesting stories to tell about past great scientists. This short paper tells the story of two French scientists, both of whom were great communicators of science to their generation. The younger of the two scientists used his knowledge of science in heroically keeping Paris in touch with the outside world when it was besieged.

INTRODUCTION
Pierre Paul Dehérain was born on 19th April, 1830 in Paris. He received his secondary education at the Collège Municipal Chaptal and then obtained the diplomas of Bachelor of Letters in 1847, and Bachelor of Sciences in 1849 (Wisniak, 2012). He studied chemistry under Edmond Frémy from 1850 and obtained his L.Sc degree in 1856 (URL: Chemeurope) in 1859, at the age of 29, he received his degree of Doctor of Science for his thesis on chlorine salts.

Gaston Tissandier was born in Paris on November 21st, 1843. He was the second son of Paul Emmanuel Tissandier and Caroline Agathe Decan de Chatouville. His secondary schooling was at the Lycée Bonaparte, Paris. Tissandier studied in the chemistry laboratory of P. P. Dehérain at the Conservatoire des Arts et Metiers. Paris. He then took further courses in chemistry at the Sorbonne and the College de France. In 1864, at the age of twenty-one, he became Director of the Laboratory of Tests and Chemical Analysis of the Union Nationale. Over the next three years he co-authored, with Dehérain the four volume Elements of Chemistry (De Lorenzo, 2008, 1393-4: Dehérain and Tissandier, 1870). He married Louise Anne Arbouin and they had two children.

THE SCIENTISTS’ CAREERS
Through amazing hard work and dedication, Dehérain slowly worked his way up the system. Finally, in 1880, he was appointed by decree 'Professeur Administrateur' of the Vegetable Physiology applied to Agriculture Chair at the Muséum d’Historie Naturelle. His research was as a plant physiologist with an interest in chemical processes (plant physiological chemistry), researching into the absorption of
carbon dioxide by plants and the effect of artificial light such as ultra violet rays on them (Mainz and Girolami, 1998).

He showed that plants do not absorb only those minerals that are beneficial, as previously thought, but absorb all of them and then use those that they need - so that consumption regulates absorption. He discovered respiration by plant roots and investigated the effect of different minerals on the growth of fruits. He also studied effect of crop rotation on soil quality (URL: Chemeurope).

Wisniak (2012) provides a much fuller account of Dehérain’s research. Dehérain’ wrote a series of nine articles about the science of growing wheat in the American journal, Popular Science Monthly (Dehérain, 1896). He wrote more widely about the history of science, including an account of the discovery of the composition of water. He also founded the journal Annales Agronomiques, under the auspices of the French Ministry of Agriculture. Perhaps it was his communication that improved wheat production in the United States through popularising his scientific results so that the USA has become the ‘breadbasket’ for the world.

Dehérain had two doctoral students who achieved public acclamation, Henri Moissan and Gaston Tissandier. Henri Moissan obtained the 1906 Nobel Prize for chemistry (Stock, 1961, p. 978). Gaston Tissandier achieved great fame through his ballooning exploits and his bravery in the Siege of Paris.

Tissandier started his career in chemistry helped by P. P. Dehérain. However gradually his interests expanded and he wrote a number of books for Libraire Hachette for the ‘Library of Marvels’ beginning in 1867. The first book in this series was ‘Water’. He became one of the mid-nineteenth century professional popularisers of science who devoted their lives to explaining the latest science to the general public (Homburg, 2006). Similarly, Nye (1991, pp. 980-981) reviewing La Science pour tous places Gaston Tissandier amongst the top five popular science writers of his era. In 1873, Tissandier established his own illustrated scientific journal La Nature (De Lorenzo, 2008, 1393-4) and its success is attested to by the fact that subscriptions to La Nature increased from 2000 in 1873 to 15,000 in 1885 (Nye, 1991, pp. 980-981).

TISSANDIER AND BALLOONING

Tissandier was probably best known as an expert in scientific ballooning which he started 1868. In 1870-1871, Tissandier and other balloonists helped to relieve the siege of Paris by transporting people, mail and carrier pigeons over the Prussian lines (Kotar & Gessler, 2011, p. 219: Brady, 2000, p. 315). Messrs Sivel, Croce-Spinelli and Tissandier went on a scientific balloon flight from the gasworks at La Villette, Paris on Thursday 15th April 1875 and the balloon accidentally ascended to a height of 8600 metres (Reporter 1, 1875). Tissandier was the only survivor of this flight and became deaf as a consequence but nonetheless he continued with ballooning. In 1881, Gaston Tissandier and his brother Albert carried out a series of trials with an electrically powered balloon by attaching an
electric motor to an airship which resulted in the world’s first electric-powered flight (Silva de Mattos, 2012, p. 356). Tissandier (1884a: 1884b) gave an account of the construction and flight of his electric balloon which gave his balloon the power to move independently of the wind. Gaston Tissandier’s death on 30th August 1899 was widely reported, not just in France but worldwide (Reporter 2: Reporter 3, 1899).

**CONCLUSION**

Probably, few people today have heard of Gaston Tissandier or Pierre Paul Dehérain. Each of these two scientists have left a valuable legacy. Dehérain had a fairly standard scientific career characterised by hard work and ability. He managed to improve the world’s understanding of photosynthesis, possibly assisting grain production in America. It is curious that such a quiet man should have had as his doctoral students a Nobel prize winner and a French National hero. Gaston Tissandier was exceptionally brave in flying mail and intelligence in and out of Paris during the German siege by balloon, dramatically showing the use to which balloons might be put. His further scientific investigations using balloons were also valuable. His illustrated scientific journal La Nature brought science into the understanding of ordinary people. Both Dehérain and Tissandier proved to be effective scientific communicators.

**REFERENCES**


Introduction

Recent research reports on the teaching and learning of mathematics and science in Lesotho show that teaching remains dominated by teacher centred approaches with minimal students’ talk (eg. Qhobela & Moru, 2014). We have documented efforts by pre-service teachers to make students talk science during Teaching Practice (TP) as part of their training to engage learner centred approaches (Qhobela & Moru, 2016). A peculiar finding in those efforts is the fact that many pre-service teachers opted for making students talk science mainly through group work. The purpose of this paper is to report on how pre-service teachers practiced classroom talk among themselves during their fourth-year physics education course. The paper responds to the following research questions: What is the nature of the classroom talk practised by pre-service teachers? and what is the purpose of the classroom talk pre-service teachers practiced?

Theoretical Background

Studies drawing their theoretical framework from sociocultural perspectives of learning acknowledge the value of classroom talk in the process of teaching and learning. According to sociocultural theory learning occurs in social activities, it is discursive and is a cultural process (Leach and Scott, 2003). Understanding sociocultural theory requires understanding Vygostky’s (1978) contribution towards unpacking the difficult notion of learning. The first is the internalisation in which the basic tenet is that “Every function in the child’s cultural development appears twice: first, on the social level, and later, on the individual level; first, between people (interpsychological), and then inside the child (intrapsychological).” (Vygotsky, 1978:57). The second in the ZPD that is defined as “…the distance between the actual developmental level as determined by independent problem solving, and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers.” (Vygotsky, 1978:86). Classroom talk, must comprise of students being able or assisted to argue a viewpoint, making and describing an observation, and reaching some level of intersubjectivity.

Literature shows that there are different patterns that surface when teachers and students talk science. For instance, Mortimer and Scott (2003) describes four communicative approaches between
students and their teacher; namely non-interactive authoritative, interactive authoritative, non-interactive dialogic, and interactive dialogic.

**Methodology**

This qualitative study reports talk within two groups of pre-service physics teachers at the National University of Lesotho (NUL). The pre-service teachers were in their fourth year of BSc.Ed. and were enrolled in Curriculum Studies in Physics. This course, offered by the first researcher, introduces pre-service teachers to the teaching of physics and includes topics such as theories of learning, teaching strategies, practical work in physics, and assessment in physics. Data were collected from two groups, group 1 that had three pre-service teachers (two females; ST11 & ST13, and one male, ST12) and group 2 that had two pre-service teachers (two males, ST21 & ST22). The pre-service teachers were asked to voluntarily audio record their discussions as they were doing classwork during lectures and voluntarily submit the audio records to first researcher. The audio records analysed in this paper come from two lectures; one at the beginning of the course and the other towards the end of the course. The submitted data were transcribed and analysed with emphasis on how members of a group talked about and constructed meaning.

**Results**

In the first lecture pre-service teachers were asked to discuss the best ways of teaching physics. Extract 1 below shows a discussion of members of group 1.

**Extract 1**

ST13: physics can be taught basically by
ST12: experiments
ST13: practicals
ST12: what are you saying?
ST13: by by experiments, it can be taught best by experiments (*ST11 is writing*). Either by allowing students to do experiments for themselves
ST11: (*saying after ST13 and writing*) either by allowing students to do experiments for themselves

The three pre-service teachers played different roles. ST11 called for contributions from both ST12 and ST13. ST12 quickly gave a response that is accepted by ST13 but noted that they are using different terms “experiments” and “Practicals”. The question he asked made ST13 to elaborate on what she was referring to. It is important to note that in this extract there is no justification either given by ST13 or demanded by ST12 and ST11.

The extract below shows a discussion of a good physics teacher by group 1 members.

**Extract 2**
ST11: that is why I say s/he facilitates, in that way when he facilitates s/he does not do things for students, s/he does not impose content, s/he allows them to discover content, they do things for themselves so that
ST13: he/she should facilitate …
ST11: Yes!! By allowing them to do things by themselves, and then do demonstrations
ST12: so that they can see that
ST11: s/he allows them to do, he gives them

The extract above shows ST11 justifying the notion of “facilitating” that she believes characterises a good physics teacher. She attempted to bring together ideas of ST12 and ST13. The extract below shows a discussion of pre-service teachers in group 2. The discussion was about why they want to be physics teachers.

Extract 3
ST21: Yes! You can study physics to be a physicist is it not so?
ST22: Yes!
ST21: is it not so? That is, you captured that interest of of this learner so that he ends up doing this physics in future, is it not so?
ST22: Yes! now the other thing is that ehh even if they do not study physics but you inspire them to become scientist, maybe they can do their research, not exactly not necessarily to become physics teacher like you

In the above extract ST21 and ST22 are discussing why they want to be physics teachers. ST21 had to justify that being inspired to become a scientist is the same as being inspired to become a physicist. The next two episodes come from talk coming from activity at the end of the course. The pre-service teachers had been in a ten-week TP and were reflecting on it. In the extract below the pre-service teachers are discussing characteristics of a good physics teacher.

Extract 4
ST12: S/he is always punctual
ST13: good physics teacher is always punctual, s/he plans his lessons in advance or in time
.....
ST12: s/he plans this thing in time, plans the lesson in time
ST13: the thing, I think, s/he, physics teacher varies ways of teaching, s/he does not say I taught this topic last year, I taught this topic like this last year
ST12: I am going to teach like that
ST13: I am going to teach like that, s/he varies ways of teaching according to the kinds of students s/he teaches

In the above extract, in which ST11, ST12 and ST13 are discussing characteristics of a good physics teacher, the three pre-service teachers are taking turns to contribute ideas. None of the pre-service teachers justified their opinion.
In extract 5 below ST21 and ST22 are discussing characteristics of a good physics teacher

Extract 5

ST21: the other thing is this thing that they should produce models. If there is shortage or unavailability of material, he practices this, then the use of models should take place

ST22: Yes!! Another one is to try to make students, when they do experiment, they should try to, they should try to .... No, will still guide them in here and there. Not necessarily do the experiment for them, giving them everything

ST21: Yes! That means you have to ...

ST21 and ST22, in the above extract, contributed ideas. They both justified their opinion.

Discussion and Conclusions

The discussion above shows that the pre-service teachers consider physics to be best taught using experimentation. They see the role of the teacher as to facilitate and to act as a role model for students.

The data in this paper shows pre-service teachers contributing ideas. They sometimes justify their talk and in other incidences they do not. The talk they engage is sometimes directed towards contributing ideas and/or sometimes meant to justify ideas. The discussions demonstrate how classroom talk encouraged knowledge sharing and/or construction.

References


PRE-POST-TEST: An Assessment Technique for Accessing Electricity Knowledge on Grade 11 Physical Sciences Learners
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Abstract

Pre-post-test is an assessment technique which comprehends evaluation of learning process so as to source useful information on learners’ understanding of concepts which exist in their schema. This mixed method study is underpinned by interpretive paradigm. Quantitative data were sourced through written pre-post-test and qualitative data were sourced through stimulated recall interviews on twelve purposively sampled Grade 11 Physical Sciences learners. The sourced data revealed that pre-post-test signalled prior knowledge that enabled or inhibited sense making of electricity concepts.

Keywords: electricity; pre-post-test; testing; assessment technique; assessment for learning; prior knowledge; sense making

Introduction

Test is a form of assessment which is used to determine learners’ ability to demonstrate their understanding based on their prior knowledge. In this study, test and testing are used interchangeably. Pre-post-testing afforded the first author an opportunity to access electricity knowledge whilst being cognisant of the background information about the participants’ home language being IsiXhosa or Sesotho which led to a different language of learning and teaching (LoLT). In this study, pre-test was used as a formative assessment which helped to identify learners’ needs in preparation for an intervention process and it revealed prior knowledge that learners came with into a science class. This study focused on Grade11 Physical Sciences electricity concepts which are also summatively assessed and reported in Grade 12 (see Table 1 below).


<table>
<thead>
<tr>
<th>YEAR</th>
<th>PERCENTAGE</th>
<th>ACHIEVEMENT POSITION (out of nine or ten examined topics)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>12 %</td>
<td>Last</td>
</tr>
<tr>
<td>2014</td>
<td>47 %</td>
<td>Five from the last</td>
</tr>
<tr>
<td>2015</td>
<td>41 %</td>
<td>Third last</td>
</tr>
<tr>
<td>2016</td>
<td>40,5 %</td>
<td>Second last</td>
</tr>
<tr>
<td>2017</td>
<td>51,1 %</td>
<td>Second last (topic on electrodynamics at 43,3%)</td>
</tr>
</tbody>
</table>
With reference to the annual Examiners’ reports on sampled Grade 12 scripts, over the past five years, learners have been performing on the mean score of 50% in Eastern Cape Province, South Africa (Examiner’s report, 2013 - 2017). There has been a slight improvement although the topic on electrodynamics which deals with application of electricity concepts dropped to less than 50%. It is against this backdrop of continuous underperformance on electricity concepts that the first author decided to undertake this study. This study focused on Grade 11 electricity concepts which are developed from primary classes up to Grade 10, and then subsequently examined in Grade 12 as informed by the South African Curriculum and Assessment Policy Statement for Physical Sciences in Grades 10 – 12 (Department of Basic Education (DoBE), 2011). This study sought to reveal the significance of pre-post-test and intervention plan on accessing electricity knowledge that learners had. The study thus sought to answer the following research questions:

1. What prior electricity knowledge do Grade 11 Physical Sciences learners have?
2. How do Grade 11 Physical Sciences learners make sense of prior electricity learning to inform new knowledge?

For this study, data from pre-post-testing was not used for comparison purposes but instead for accessing learners’ prior knowledge in the learners’ minds. In Ramaprasad’s (1983) terms, critique on the actual knowledge that learners have put value on feedback. This study was grounded on previous literature.

**Literature Review**

In this study, it is emphasised that accessing knowledge in the learners’ minds might be influenced by blending aspects such as prior knowledge, testing, language usage and mathematical skills drawn from the previous literature. Prior knowledge may consist of concepts which were well or poorly understood during previous learning contexts. Testing is a process used to check on prior knowledge and experiences as teaching and learning takes place (Shepard, 2000). Testing of prior knowledge helps to supply feedback to be used in strengthening correct understandings and addressing incorrect understandings (Ramaprasad, 1983; Shepard, 2000; Clark, 2010). This positions testing as having a constructive element of formative assessment. In addition, testing is a learning strategy used to improve incorrect understandings and to reveal uncertainties (Dann, 2014). Sibanda (2017) opines that if incorrect understandings or uncertainties are not cleared, learners might have a challenge of recurring with such to the next classes which poses some learning barriers. Testing of prior knowledge becomes salient for learning. However, unplanned tests might create anxiety in assessing for learning. Furthermore, testing for score grading contributes in creating tension between testing and learning as it might create anxiety on learners (Carless & Zhou, 2016). Testing for scores does not support learning as it is not process focused. Language used to communicate ideas might have influenced the studies’ findings.
For instance, learners with language of learning and teaching (LoLT) which is different from home languages might develop language fluency as they alter between two or more languages (Cummins, 2001). However, language alteration might pose some barriers to testing. Probyn (2009) opines that language incompetence in relation to LoLT within the abstract science language might inhibit understanding. In addition to LoLT, science language or mathematical skills which incorporates science communication tools such as words, symbols, graphs and calculations are also used to make sense of concepts. Transforming ideas between the mentioned tools demands abstract thinking. That might be a challenge to learners who grapple with language and mathematics from primary school (Sibanda, 2017).

**Theoretical Framework**

This study is grounded on Piaget’s (1952) and Vygosky’s (1978) theory of cognitive development. This learning theory focuses on constructing ideas from experiences. The theory positions understanding of concepts as an underlying focus as it might be language rooted. Vygotsky (1978) concurs with Piaget (1952) that language is used to regulate thoughts. That is revealed when learners constructed ideas from their existing schema. Schemas are the knowledge structures that underlie all thinking (Piaget, 1952, p. 29). In this study, the process of testing or formative assessment was used to reveal prior knowledge on electricity topic stored in the individual learners’ schema. Assessment for learning furthermore narrowed the focus of this study to adopt Black and Willam’s (1998) notion of formative assessment as a conceptual framework. Assessment for learning was the main element of formal assessment used in this study. Clark (2010) opines that assessment for learning is useful if feedback provides data that is structured and hidden in the learners’ minds to improve learning. Clark (2010) further argue that assessment for learning is a framework used to support learners’ thinking and helps to decide on relevant strategies to improve instruction as well as learners’ work. In Clark’s (2012) terms, learners are engaged in reflective thinking during testing as they become aware of what was understood or not understood.

**Methodology**

The main focus of this study was to access insight into learners’ thoughts, hence underpinned by interpretive paradigm as suggested by Cohen, Manion and Morrison (2011). In this mixed method study, the collected quantitative data was purposely used for sampling and grouping learners. In addition, qualitative data through test answers and stimulated recall interviews (SRIs) were analysed and grouped into similar patterns which were categorised as themes. The analysed data were sourced from a purposively sampled focus group of twelve participants who were categorised into four members from each grouping, for instance, top, middle or average and low groupings. The heterogeneous groupings based on performance levels assisted in revealing data from a continuum of learners’ cognitive levels. Furthermore, six learners from the focus group were sampled to participate in SRIs.
The interviews were incorporated in this study for the purpose of accessing in-depth information on learners’ thought processes as they reflected on their experiences without worrying about language as they were allowed to voice out their ideas in the language of preference. In the context of this study, SRIs were used as follow-up to pre-post-test answers. Learners were given an opportunity to think on how they constructed knowledge during testing. Interviews contributed to the qualitative data which was video-recorded as consented by the participants.

Throughout the research process, ethical concerns and consent by relevant people were considered. Informed consent to participate in pre-test was orally sought in advance to all Grade 11 Physical Sciences learners. The purpose of testing, sampling of research participants as well as the study process was discussed with them. Thereafter, the consent letters were signed and the participants were allowed to withdraw their participation at any time if they wish so. The permission to video-record the interviews, use the data for research purposes and participation in testing was sorted and granted. Test process such as setting, moderation, administration, marking and analysis of test were done by competent people to ensure validity and reliability.

Validity and reliability in testing were observed throughout the study process as advised by Cohen et al (2011). Cohen et al. (2011) posit that a test must adhere to the purpose of study. The purpose of testing was to access sense making of science concepts rather than being score orientated. Content of test items were in line with evaluation of the learners’ competency in electricity concepts which was the focus of this study. The content to be examined in pre-post-tests was checked and verified to be at the learners’ level from the following documents: the Examination Guidelines for Grade 11 and Grade 12 (DoBE, 2015, 2017), the CAPS Grade 10 -12 document (DoBE, 2011) and Examiner’s reports (2013 – 2017). The pre-post-test questions were structured in a manner that they assessed the extent of learners’ understanding. Learners were mostly expected to explain their answers in order to get insight into their thoughts. To demonstrate validity, different data sources such as test answers and SRIs were used. Viewing data from different perspectives strengthened the validity and reliability of the study and minimised power relations. Such information contributed to qualitative data as insight into learners’ thoughts was the basic focus of this study. Furthermore, raw data presented in participants’ thoughts such as written answers in tests and learners’ voices during SRIs made it possible to see electricity through the eyes of the participants.

Findings and Discussions

This study on pre-post-test sought to reveal the influence of testing on accessing electricity knowledge in a Grade 11 class. This mixed method study also revealed data with common patterns which were categorised into the following themes: sense making of electricity concepts and misconstruction. The themes emerged from the analysed data were sourced from a purposely sampled focus group. Pre-post-testing might have signalled the significance of the study (Table 2 below).
**Table 2: Pre-test scores and post-test scores**

<table>
<thead>
<tr>
<th>Pseudonyms</th>
<th>Pre-test scores (%)</th>
<th>Pre-test achievement position (Pre-test scores)</th>
<th>Post-test scores (%)</th>
<th>Post-test achievement position (Post-test scores)</th>
<th>Difference (between pre-test and post-test scores)</th>
<th>Change in position (pre-post-test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cozmo</td>
<td>58</td>
<td>1</td>
<td>77</td>
<td>6</td>
<td>+19</td>
<td>Downwards</td>
</tr>
<tr>
<td>Lizzy</td>
<td>56</td>
<td>2</td>
<td>84</td>
<td>2</td>
<td>+28</td>
<td>Same</td>
</tr>
<tr>
<td>Entle</td>
<td>52</td>
<td>3</td>
<td>91</td>
<td>1</td>
<td>+39</td>
<td>Upwards</td>
</tr>
<tr>
<td>Zoo</td>
<td>48</td>
<td>4</td>
<td>66</td>
<td>8</td>
<td>+18</td>
<td>Downwards</td>
</tr>
<tr>
<td>Yolanda</td>
<td>42</td>
<td>5</td>
<td>84</td>
<td>2</td>
<td>+42</td>
<td>Upwards</td>
</tr>
<tr>
<td>Oyintando</td>
<td>40</td>
<td>6</td>
<td>80</td>
<td>4</td>
<td>+40</td>
<td>Upwards</td>
</tr>
<tr>
<td>Faith</td>
<td>35</td>
<td>7</td>
<td>73</td>
<td>7</td>
<td>+38</td>
<td>Same</td>
</tr>
<tr>
<td>Luyanda</td>
<td>35</td>
<td>7</td>
<td>80</td>
<td>4</td>
<td>+45</td>
<td>Upwards</td>
</tr>
<tr>
<td>Zodiac</td>
<td>27</td>
<td>9</td>
<td>45</td>
<td>12</td>
<td>+18</td>
<td>Downwards</td>
</tr>
<tr>
<td>Boithabiso</td>
<td>17</td>
<td>10</td>
<td>57</td>
<td>10</td>
<td>+40</td>
<td>Same</td>
</tr>
<tr>
<td>Fiona</td>
<td>15</td>
<td>11</td>
<td>64</td>
<td>9</td>
<td>+49</td>
<td>Upwards</td>
</tr>
<tr>
<td>Rebahaae</td>
<td>15</td>
<td>11</td>
<td>57</td>
<td>10</td>
<td>+42</td>
<td>Upwards</td>
</tr>
</tbody>
</table>

The pre-test scores revealed that 75% of the focus group members achieved less than 50% which showed similar results with Eastern Cape performance on electricity for Grade 12 learners (Examiner’s reports, 2013 – 2017) (see Table 1). Learners were not given answers of pre-test instead their answers were analysed and used to plan for the intervention. Thereafter, a post-test was administered based on the same topic. Stimulated recall interviews (SRIs) were done for the purpose of accessing insight on the learners’ thought processed answers. SRIs revealed data presented as excerpts. Table 3 revealed that Entle, Lizzy and Cozmo managed to score above 50% in pre-test and there was an observed improvement in post-test. However, Faith, Luyanda and Yolanda underperformed in relation to pre-test but they remarkably performed well in the post-test. The data based on post-test scored were triangulated with SRIs and some themes were generated from the data.

**Theme 1: Sense making of electricity concepts**

The following excerpts indicated that pre-post-test data drawn added value to learning.

*Faith:* “Besi-dependekwi-previouswork.(TranslationfromIsiXhosa:“Wedependedonthe previouswork’’). (pre-test)

“We did most of electricity work with calculations in Grade 10’’.

*Faith:* “Thenmasiphinda-kwi-lasttestitwasnotthatdifficulttoanswerquestionsbecausewewhadabetter understandingofelectricity’’. (TranslationfromIsiXhosa:Referringto thelasttest,itwasnotdifficulttoanswermostquestionsbecausewewhadabetter understandingofelectricity’’) (post-test)

It was revealed through SRIs that testing assisted learners to tap into their prior knowledge (Mavhunga, Ibrahim, Qhobela, & Rollick, 2016). Constructed knowledge revealed the actual
learners’ cognitive level of understanding. Faith indicated that the concepts examined in the pre-test were connected to ideas in their existing schemas. It was clearly drawn from the interview data that prior knowledge on electricity concepts made it possible for the learners to tap on previous learning as suggested by Shepard (2000). Learners were given an opportunity to think about experiences and previous work done for instance in Grade 10 as suggested by Faith. Testing to gauge the extent of previous learning was therefore aimed at establishing the concepts which were well built in the learners’ minds. Learners were allowed to show the depth and breadth of their sense making of electricity concepts before acquiring new knowledge as suggested by Piaget (1952). Constructed ideas through processing of pre-test answers revealed the actual cognitive level of understanding that learners had instead of relying on the specifications and expectations which are documented in the Physical Sciences Grade 11 curriculum. The intervention was planned to strengthen electricity concepts that learners seemed to make sense of (Clark, 2010). The effectiveness of the intervention plan was evident when all learners were able to connect the assessed ideas with the well-built electricity knowledge as shown in post-test performance. Additionally, the value of the designed intervention was evident when most learners were able to infer from their prior knowledge as indicated in difference column (see Table 2). Some of the learners were able to juggle between representing ideas in words, symbols, graphs and calculations to a certain degree as represented in Figure 1 below.

![Figure 1: An example of potential difference versus electrical current graph (pre-test).](image)

The learner was able to plot and join the points, draw a graph, use uniform scale and label both axes. That revealed the possible connection to prior learning and learners’ sense making of the given data to present it differently within science space. On the other hand, most of the learners showed some traces of misconstructions.

**Theme 2: Misconstructions**

It can be drawn from Figure 1 that the learner could not properly use the correct symbols for potential difference and electrical current. In addition to that, graph labels were not accompanied by their
units of measurements. The graph showed that the learner had fragmented knowledge on joining the plotted points as that shows the relationship between variables when the ‘line of best fit’ is done. The inability to establish the relationships between variables hindered science reasoning. Most of the learners in various groupings had a challenge of interpreting graphs, such as Zodiac and Lizzy. They struggled with gradient calculation (Figure 2 below).

![Figure 2: Zodiac’s gradient calculation (pre-test).](image)

It may be applauded that Zodiac had an idea that gradient is a ratio of change in values. He knew that gradient relates a change in y-values and x-values although the whole gradient concept was misconstructed. The fragmented prior knowledge led to uncertainties although he decided to substitute the y-values in the x-values and vice versa (Dann, 2014). According to Sibanda (2017) unattended misconceptions continues as learners progresses from lower classes to the next classes. Such misconstructions of ideas might negatively impact on Grade 12 final results (see Table 1). The first author expected the learners to master this gradient concept because it is dealt with in lower classes in mathematics. Using the data shown in Figure 1, the first author decided to engage Zodiac in SRIs for the purpose of getting insight into his thoughts and the interesting data was gathered and revealed misconstructions he had (see the excerpt below).

Zodiac: “There was misunderstanding... ezinye lianswer ndizibhidanisile. Like kwi-potential difference and current”. (Translation from IsiXhosa: There was misunderstanding ...I exchanged some of the answers such as with potential difference and current).

“Well, because I was not sure which one goes to the numerator or denominator”.

Zodiac indicated to have ‘misunderstanding’ of gradient calculation when explaining his working details shown in Figure 2. There were traces of uncertainties as indicated in the substitution (See Figure 2 and the excerpt above). The uncertainties might have resulted from the poor or fragmented prior knowledge which led to confusion. It was noted that Lizzy, one of leaners from top grouping, also struggled with the gradient concept as well (see Table 2). If she was not interviewed, the assumption would be that she did not have a challenge with some of the mathematics skills (see the excerpt below).
The data revealed that Lizzy was as confused as Zodiac for the reason that she took a long time to recall that gradient calculations are not new to her. It is apparent that Lizzy also had fragmented prior knowledge on gradient calculations which led to uncertainties. According to Sibanda (2017) unattended misconceptions recur as gradient concepts are introduced in primary school and the concept is mostly dealt with in Mathematics. Integration within science subjects and the graph interpretation of electricity concepts was a challenge to most of the learners. It could be concluded that some of the mathematics skills might be a challenge to learners across almost all the cognitive levels.

Through SRIs we were well grounded on the aspects that need more focus as they hinted misconstructions. Concepts where learners made sense and do show signs of misconstructions were taken cognisance when developing an intervention plan as well. The intervention plan was solely designed to strengthen learners’ conceptualisations and clarify misconstructions whilst building on established electricity concepts. Post-test and post-test scores in Table 2 revealed that the study where learning is observed and monitored addresses learning needs. The assessment technique of pre-post-test placed testing at the hub of learning.

Concluding Remarks

The assessment technique of pre-post testing incorporated in this study revealed how learning progress can be monitored. Learning progress signalled the level of cognitive development (Vygotsky, 1978). Testing was at the hub of learning as shown when the learners signalled the points of needs, the researcher was able to support them irrespective of being in different cognitive levels. The impact of the study was cognisant when both the researcher and participants had an opportunity to reflect on the teaching and learning journey through testing process and stimulated recall interviews. Through testing and interviews, construction of ideas was encouraged to take place from established prior knowledge. Furthermore, intervention plan was designed to strengthen well-built ideas and clarify poorly or fragmented prior knowledge. The impact of pre- post-testing revealed that testing promoted learning by all learners in different cognitive levels. It can be argued that the findings of this study cannot be generalised because the purposively sampled group was small although it represented a broader continuum of cognitive levels.

References


THE EFFECT OF INTEGRATING LOCAL KNOWLEDGE ON FOOD PRESERVATION ON LEARNERS’ CONCEPTIONS AND ATTITUDES IN A MULTICULTURAL GRADE 6 CLASS

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Abstract
The National Curriculum for Basic Education (NCBE) requires teaching to tap into the wealth of knowledge that learners bring from home to contextualize science. Despite these ideals, however, it is silent on how to go about doing this. As a result, some science teachers find it to be a challenge teaching learner from diverse socio-cultural backgrounds. It is against this backdrop that this study aimed at investigating the effect of integrating local or indigenous knowledge on learners’ conceptions and attitudes towards science in a multicultural grade 6 class. The study is underpinned by an interpretive paradigm. Within the interpretive paradigm, a qualitative case study approach was employed. Data were generated using a group activity, observations and journal reflections. The findings of the study revealed that integrating IK in science lessons in a multicultural class aroused learners’ interest. The study thus recommends further research on how IK could be integrated in multicultural classrooms.

Key words: Agricultural Science, scientific knowledge, local or indigenous knowledge, conceptions, attitudes, multicultural class, socio-cultural theory

Background and Purpose of Study

Generally, there is a decrease in learners’ interest is science (Welch, 2010). Our assumption is that this is compounded in part by the fact that science is taught in decontextualized ways and hence affecting learners’ attitudes. Pell and Jarris (2001) highlight that there is a positive correlation between positive attitude towards science and achievement in it. Additionally, Wang and Huguley (2012) revealed that learners who are engaged in cultural socialization by their parents had better academic achievement than learners who do not engage in these practices.

There are a number of factors as to why learners’ interest is declining. To mention a few, the inability of some teachers to make science meaningful and interesting to learners; the gap between what learners know from home and what they are learning from school (Aikenhead & Jegede, 1999; Le Grange, 2007); neglecting of learners’ diverse socio-cultural contexts (Govender, 2014; Mavuru & Ramanarain, 2017); and learners’ conceptions toward science (Tsai, 2003). In our view, some of these challenges could be addressed by considering the learners’ everyday experiences and local or indigenous knowledge. It is against this background that in this study we investigated the effect of
integrating local or indigenous knowledge on food preservation on learners’ conceptions and attitudes. The study thus sought to address the following research question:

What is the effect of integrating local or indigenous knowledge on food preservation on learners’ conceptions and attitudes?

**Literature review and Theoretical Framework**

Teaching should begin from the wealth of knowledge and experiences that learners gained from families, community and through interaction with the environment (Ministry of Education, NCBE, 2015). In his study, for instance, Ogunniyi (2007) revealed that learners are loaded with a lot of science from their home background that a teacher can take advantage of. Learning becomes effective when learners’ cultural resources from diverse cultural backgrounds are harnessed (Cocks, Alexander & Dold, 2012; Mhakure & Otulaja, 2017). It is for these reasons that we deemed Vygotsky’ (1978) socio-cultural theory as an appropriate theoretical framework for this study.

Vygotsky emphasizes that culture provides tools that enable mediation of learning. Vygotsky also believes that every function in a child’s cultural development appears twice. First on the social level and later on their individual level. In other words, learners learn new things as they are engaged in activities with other learners, parents and teachers. Later they then internalize this knowledge which becomes part of their cognitive development. To Lemke (2001), this cultural perspective guides the construction of meaning making across many domains of social life. Thus, this theory provided cultural lenses on how learners crossed borders from home to school science (Aikenhead & Jegede, 1999).

**Research Design and Methodology**

This study is underpinned by an interpretive paradigm. The interpretive paradigm aims at understanding the subjective world of human experience (Cohen, Manion & Morrison, 2018). Within the interpretive paradigm, a qualitative case study approach was employed and we worked with a small sample of learners (Bertram & Christainsen, 2015). The study was conducted at one urban school with grade 6 learners in the northern part of Namibia. The school was purposively chosen because it is composed of learners from diverse socio-cultural backgrounds. Additionally, the topic on food preservation is only offered in grade 6.

A class of 29 learners voluntarily participated in this study. In addition, four community members, a Damara, Herero, Oshiwambo and Portuguese, also participated. These community members were selected based on the cultures represented in the case study class. As proposed by Vygotsky (1978), these community members were regarded as more knowledgeable ones in their cultural practices, in particular, preservation of milk, meat, mahangu and fish. Data were generated using a group
activity, observations and journal reflections. Data were analysed inductively and in relation to the research question.

Findings

It emerged that teaching learners in their context stimulated their interest. As a result, learners were actively involved during the various presentations by the community members. In their journal reflections, learners indicated that lessons presented by the community members were very interesting, and they indeed enjoyed them. This finding resonates with Klein’s (2011) study conducted with the Nama people in Namibia. Hence, it could be argued that teaching using demonstrations with concrete materials from home added value to the lesson. This also contributed to more meaningful learning amongst the learners. The findings further revealed that integrating IK in a multicultural class resulted in cultural revitalization (Cocks et al., 2012) as learners seemed to appreciate and respect each other’s cultures.

Conclusion and Recommendation

Contextualizing science by integrating IK in teaching increases learners’ interest and promotes positive attitude toward science. For meaningful learning to take place, teachers should involve relevant experts from their communities when teaching science. This could help to bridge the gap between home and school. Aikenhead and Jegede (1999) refer to this as border crossing. It also emerged from this study that multicultural classrooms have a potential to be a source of wealth of knowledge rather than a disadvantage. Hence, Mavuru and Ramnarain (2017) emphasize the importance of taking into consideration learners’ socio-cultural backgrounds during teaching and learning repertoires. Concurring, Mahakure and Otulaja (2017) advocate for culturally responsive pedagogies in science classrooms. The study thus recommends further research in the area of multicultural teaching, particularly on how best to integrate IK.

References


ADDRESSING THE TEACHING OF SENSITIVE HUMAN REPRODUCTION CONTENT BY GRADE 12 LIFE SCIENCES’ TEACHERS: Implications of Indigenous Culture in Teacher Practice
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Abstract
The paper represents our first attempt to come to terms with the socio-cultural dynamics of teaching human reproduction structures by teachers of the same ethnicity as the learners in South Africa. Given the previous history of marginalized Black people in South Africa, the paper seeks to increase understanding of how isiXhosa speaking ethnic group teach sexual reproduction in Grade 12 when the community does not talk publicly about sexual terminology. Specifically, our theorising attempts to explore the prevailing indigenous cultural beliefs, attitudes, practices, values and language that teachers of isiXhosa culture experience when teaching sensitive sexual content in Life Sciences classrooms. The principal argument of this paper is that; prevailing views in how society views sexual-related biology content are socially produced. Furthermore, the debate is heightened by the view that when cultural beliefs that contribute to the emancipation of previously colonized communities are restored; the individual will see the value of their beliefs and practices. Thus, recognition of indigenous language and gestures drawn from familiar cultural practice in teaching is a strategy that seeks to restore the dignity and respect of the oppressed communities. Argument is raised in the paper about the dilemma faced by teachers where English is the medium of teaching and learning whilst biological terminology is not available in the lexicon of isiXhosa speaking teachers and learners. The paper concludes with words of caution about teaching human reproduction anatomy and physiology without linking content to indigenous cultural knowledge of isiXhosa people.

Keywords: human reproduction; indigenous cultural knowledge; marginalized Black people; isiXhosa speaking; lexicon

Introduction
This paper makes a tentative exposition on how indigenous, isiXhosa speaking teachers teaching in multi-deprived schools (Gunter, 2017; Maringe & Moletsane, 2015) of the Eastern Cape, teach the structure and functions of human sexual reproduction organs. The Eastern Cape Department of Education bears the footprint of marginalization (Chilisa, 2005), characterised by a low Grade 12 pass rate, poor school infrastructure and low parent income group (Chilisa, 2012; Province of the Eastern Cape, 2018). Our theorising is initially targeting biology language which may not be used in class due
to culturally-sensitive issues related to naming and using sexual terminology in African cultures (Levinson, 2006; Oulton, Dillon, & Grace, 2004).

Literature

Prominent literature reviewed in this paper focuses on the nature of Grade 12 Life Sciences curriculum, language, culture and multi modal strategies that can be used to teach culturally-sensitive human reproductive systems in multi-deprived South African contexts (Maringe & Moletsane, 2015).

Life Sciences’ curriculum

The curriculum content is prescribed nationally by the Department of Basic of Education and forms part of Life Sciences Grade 12 examinable content, covering the structure, labelling and functioning of human male and female reproductive organs (S.A, DBE, 2017). Human reproduction includes the structure of the male and female sexual reproductive organs, formation of sperm cells and ova, fertilization, pregnancy, hormonal control and homeostasis; carrying 57 marks out of 150 examinable questions in Paper 1, Grade 12 external examinations (Isaac et al., 2013; S.A, DBE, 2011; 2017). Yore and Treagust (2006) in Webb (2009) affirm the need for integrating language and culture with biological science, citing the “three-language” problem (p. 331) found in most science teachers; noticeable in casual language used at home, language of instruction at school and language of science. Accordingly, this paper supports the use of standard, biological terminology for sexual terminology instead of using euphemisms and colloquialisms (Buni, 2013; Doidge & Lelliot, 2016).

Role of culture and language

Triandis (2018) contends that culture is linked to language, at a particular time and place. Also, this paper takes the stance proposed by Triandis (2018) and posits that culture is a ‘collective phenomenon’ (p.4). Collectivism considers views that individuals born into extended families (Triandis, 1995), protect each other based on a sense of exchange for loyalty to family. Furthermore, Triandis (1995) suggests that views are determined by the group, the group is more important than ‘I’ (p. 508) and when individual does something wrong, the individual is overwhelmed by feelings of shame. It is imperative that teachers should note that societal, national and gender cultures that learners acquire from childhood are deeply embedded in the human mind more than occupational cultures learnt at school (Hofstede, Hofstede & Minkov, 2010).

The challenge of missing vocabulary in both the teachers’ and learners’ isiXhosa Home Indigenous culture and human reproduction Language is quite challenging. For example, the current English-Xhosa dictionary does not have specific isiXhosa words, not even colloquial terms to serve as labels of the parts of the female reproductive system except for the uterus (Uterus, 2017). In terms of biological curriculum content for Grade 12 assessment, the female reproductive system has the following distinct parts connected to each other; two ovaries producing ova, a fallopian tube (oviduct) extending from each ovary, a ‘pear-shaped hollow organ with muscular walls’ (Isaac et al., 2013, p.
46) called uterus, vagina (birth canal) and lastly the external opening called the vulva. Noting that teaching about sexual organs is a common problem facing teachers of all races, evident in a study where parents in New England did not accept the use of explicit teaching of sexuality like ‘penis’ and ‘vagina’ (Buni, 2013, p.2) in an English First language class. The problem is compounded in Sub-Saharan Africa by tradition and cultural practices that prohibit the use of sexual terminology and collectivism, beliefs about own way of doing things are valued highly in society.

**Multimodality as a teaching strategy**

The study is underpinned by the notion of multimodality as a cultural-responsive and culturally sensitive teaching strategy (Gay, 2010) and recognizes the use of signs, symbols, images, actions, culture as parts of communicative language embedded in the context of the individual (Jewitt, 2008). Multimodal teaching is used in the study to refer to the use of communication media such as verbal interactions, actions, songs, signs, symbols and visual image (pictures) that have been developed through social usage in one’s environment (Jewitt, 2008). Hence, multimodality is viewed as an integrated teaching approach (O’Halloram, 2008) in contrast to traditional teaching characterized as “chorus teaching, repetition, memorization and recall” (Webb, 2009, p. 330).

**Way forward**

The integration of indigenous culture with sensitive biology topics remains central to improve the teaching skills of isiXhosa teachers, working in multi-deprived high schools. The paper cautions teachers against mere traditional chalk and talk, instead teachers are encouraged to use multi modal strategies that can transcend language barriers due and or cultural taboos. It remains a challenge whether the Department of Education would support ethnic isiXhosa teachers to gain teaching skills so that the two aspects; indigenous cultural knowledge and teaching of human sexual organs may be a reality. Therefore, the study is critical as it puts the African teacher at the center of transforming education of marginalized communities with the aim of improving teaching of cultural sensitive topics in human reproduction to fit their own school contexts.

**References**


PROMOTING RESEARCH-BASED OPPORTUNITIES FOR FIRST YEAR PROGRAMMING LEARNERS: RELEVANT AND QUALITY INFORMATION TECHNOLOGY EDUCATION

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ABSTRACT
The purpose of the study reported on in this paper was to answer the research question: To what extent is learner-centred education created on the Learning Management System (LMS) for first year programming subjects in an Open Distance e-Learning (ODEL) environment adopted by learners? The importance of this is justified in that the study responds to a call for improved learner pass rates, especially for Information Technology (IT) subjects offered in ODEL environments. A literature review drawing on the latest and most relevant research results on the topic investigates issues related to learner-centred education and open distance e-learning. The study is located within a relevant theoretical conceptual framework regarding LMS technologies, including learning units, announcements, discussion forums, online meetings, self-assessments, and blogs. The importance of issues of dependability and interpretation were considered in terms of the qualitative design used as research methodology. The discussion of the findings from the empirical research undertaken is based on the responses received from participants, relating to learner-centeredness and the adoption of LMS technologies. The paper suggests what the implications of the results could be for possible future use in these and related subjects. By contextualising the teaching approach in terms of the value of the findings, recommendations are made that are applicable and useful to the wider e-learning community, on the use of LMS tools in a fully online environment for the implementation of learner-centred teaching in a programming subject. In conclusion, the research question set for this study is answered. Proposed future research on the adoption of learner-centeredness makes an original contribution towards scholarly debates in the field, including for IT subjects presented in ODEL environments.
A CULTURAL RESPONSIVE PEDAGOGY FOR TEACHING DESIGN SKILLS IN TECHNOLOGY: AN INDIGENOUS PERSPECTIVE

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ABSTRACT
Technology teachers have been trained to use only western teaching pedagogies to teach design skills. This study sought to establish the role of other pedagogies such as culturally relevant pedagogy (CRP) in teaching design skills. The researchers used observations and interviews to collect data from Grades 7 – 9 Technology teachers. The four Technology teachers were interviewed in order to establish their beliefs and views about the role of CRP in teaching design skills. The participants were observed during their teaching design skills using CRP in order to find out the effectiveness of CRP. Qualitative methods were used to analyse data. The study found that the use of CRP can play a crucial role in the integration of indigenous knowledge (IK) in teaching design skills. The integration of IK through CRP can help motivate learners to acquire design skills. The findings also revealed that the use of CRP can enhance promote learners’ creativity. The observations showed that Technology learners are much captured in acquiring design skills when CRP is used to help learners to acquire design skills. The barriers to teaching through the CRP were discovered, such as Technology teachers’ inadequate knowledge of CRP and a lack of indigenous artefacts in schools. This paper concludes that Technology teachers should be conversant with the teaching strategies such as discussion and experiential teaching methods in order to be able to incorporate the CRP successfully in their teaching. This will help to achieve the main purpose of education in delivering relevant education for all learners.

Keywords: Culturally relevant pedagogy, indigenous knowledge, design skills.
MULTIMEDIA-AIDED DESCRIPTIVE GEOMETRY LEARNING

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The present study deals with the multimedia applications in education whose primary function is to facilitate the process of teaching and learning. Since Descriptive Geometry is a subject that is often considered difficult to understand, and taking advantage of the possibilities that the technology offers, the multimedia application was developed for Descriptive Geometry Bachelor’s Degree students in Visual Education and Civil Engineering at Pedagogical University. The study is multimedia-based theory of cognitive learning (Mayer, 2014). Methodologically, the study inquires 138 students from the Pedagogical University and the Gaza border and branches from the 1st and 2nd years of Civil Engineering and Visual Education courses, divided into two groups: experimental and control based on a simple random sample. The emerging results of the study from the comparison yielding diagnostic test administered pre and post testing of the multimedia application que has used the correlation of obtained marks; it was found that there is strong positive correlation of the marks between the control and experimental groups which is statistically significant. The students' learning improved due to the use of the multimedia application because it integrates a variety of average que included animations, static images and text allowing students to learn by exploring these resources becoming more appealing to the facilitated them valuing their learning experience. It is suggested, that the use of multimedia applications in the process of teaching and learning descriptive geometry should not, amongst methodologies, replace teacher's role, rather they can combine three-

Keywords: Multimedia applications; learning; Descriptive geometry.

Introduction

This study aims to develop a multimedia application for learning Descriptive Geometry by students of Degree courses in Visual Education and Civil Engineering at the Pedagogical University. It is an application for initial use by students’ 1st and 2nd years. Although the study’s focus is Descriptive Geometry learning assisted by multimedia applications, it also evaluated the usability (ease of use) of multimedia application. These multimedia applications are resources that combine via text computer, graphics, images, video, audio, animation, and any other means by which information can be represented, stored, transmitted and processed in digital form, where there is at least one type static medium (text, graphics or pictures) and a type of dynamic media (RIBEIRO, 2007).

The study looks into improving didactic tools para make the teaching process more adjusted to the learning of students and the need to integrate various mediaestão rise to the development of the
study. The gains from the production of isolated teaching resources, or its administration separately, are often weaker in the administration of the same in an integrated manner. The integrated use of teaching resources improves student learning and enables their potential skills (learning through video, images, audio).

To evaluate the ease of use of the application (usability) we used the SUS questionnaire (System Usability Scale). It should be noted that the evaluation of the multimedia application by students only became effective after its appreciation for geometry lecturers. The aim of this study is to conceive a multimedia application to enhance the learning of students of higher-level courses in Visual Education and Civil Engineering in Descriptive Geometry at the Pedagogical University. The research strives to produce navigation structure, multimedia application storyboards and content (video, text and image) of Descriptive Geometry to be allocated in the media application; test the multimedia application with students of Civil Engineering Education Visual to validate it and use; and to compare the performance of the students in the control and experimental group was administered the diagnostic test.

Statement of the problem

The singled use of resources for learning an area of knowledge such as geometry, is not always appropriate to the universe of students’ perception is not uniform. The use of resources with varying capabilities promotes the complementarity of the same. Rock & Marcelo (1995, p.50) backs Weitheimer, Kohler and Koffka in the 30s, and Paul Guillaume, French philosopher, who presented in detail Gestalt principles which is "part of a whole it is different from the same in another isolated part or all." Geometry learning has always been a challenge for students. Several educators in various parts of the world, aware of this difficulty, they give their contribution producing software and learning objects - applet for Geometry for distance learning; AEIOU-Descriptive Geometry software; the project space GD; the Descriptive Geometry program used in "online and offline" in order to make the process more meaningful and simplified learning. These led us to raise the departure question: How learning Descriptive Geometry can be improved if Visual Education and Civil Engineering students employ a multimedia application?

Conceptual framework

The cognitive theory of multimedia learning was created by Mayer in 2001 and focuses on how people learn from words and images. This theory is based on the premise that people learn best through the use of words and pictures that only with words. Silva & Montane (2017, p.2) point out that "the theory applies to the associated use of words and images in teaching and learning resources such as books, animations, videos, games and other productions."The multimedia learning is learning through words and images, "the words" which does not only refer to printed texts, but include speech and of writing as "images". In turn, it covers both medium static graphics (illustrations and
photographs) and dynamic (animations and videos) (MAYER, 2009 cited Silval, 2013, p.76; Silvall, 2017, p.59).

To ensure multimedia learning is not enough to combine images and words, you must also think about the characteristics of users and the rules of this combination. Silva (2013, p.77) states that "it is important for the development of a multimedia project, think of the student, so that the use of multimedia tool assists in the production of knowledge, providing a meaningful learning." Therefore, during multimedia content planning, it is necessary to take into account how the human being mind works. The knowledge of cognitive structures of the human being and the way in which these structures are organized should guide the efforts of good educational materials projects (Paas and Sweller, cited Silva 2014, 2017, p.60).

**Literature review: Multimedia Applications**

It is important to distinguish between multimedia applications and areas of use of multimedia technologies. Multimedia application designates the program, or software application, which controls the display of various media to the end user content; that is, software that performs reproduction of media combinations (multimedia presentation), whereas areas of use of multimedia technologies are the areas of human activity in which they are used applications (e.g., education, entertainment, business, public information) (p.15 Ribeiro, 2012). Gonzalez's view (2000, quoted in Ribeiro, 2012, p.16), the creation of multimedia applications that meet the objectives for which they were developed requires, first, that they build a "functional information space, designed to reduce the cognitive burden imposed on the user. "To this end, according to Ribeiro (2012, p.16,), multimedia application should:

- Facilitate access to content;
- Facilitate understanding of the information;
- Minimize complexity and consequent disorientation of the user when navigating the information space.

Multimedia systems have five main characteristics, namely: digital; still and dynamic media integration and interface. A reference model thus allows characterising a set of related technologies grouping them in the same technological field, taking into account the relative proximity to the user. In the adopted reference model are identified four areas of multimedia technologies, namely: applications and multimedia content, multimedia services, multimedia systems and representation of multimedia information (Ribeiro, 2012, p.12-15). According to Santa Rita (2000, p.8), at the higher-level education, the descriptive geometry "is a discipline that aims to develop the capabilities of students to see, perceive and organize the surroundings and the ways that it is situated,

Use of Multimedia in teaching and learning process of descriptive geometry now becomes essential to achieve better results or even to add value to the classical methodologies and widely known by the ‘players’ of this area of knowledge. Son (2000, p.27) believes that people learn, and faster when
they can see, hear and work with new concepts, which makes the media a natural means to train and educate. Thus, the integration of multimedia resources in teaching and learning process in descriptive geometry discipline proves to be important and necessary to ensure a level playing field of learning.

Methods and materials

This is a mixed-methodology study that was conducted at the Pedagogical University, headquarters and other cumpi in Xai-Xai and the Beira. The study subjects were 138 students attending 1st and 2nd years’ Civil Engineering and Visual Education courses, and 4 descriptive geometry teachers. Out of 138 estudantes, 119 (86.2%) were males and 19 (13.8%) female.

Preliminary findings: Multimedia aplication

The development phase of the multimedia project - multimedia application for learning Descriptive Geometry comprised five main phases, namely: analysis and planning, design, production, testing and validation and distribution and maintenance (RIBEIRO, 2012, p.283). In the light of these phases, the project of multimedia application is presented in form of multimedia application script. Educational multimedia application for learning Descriptive Geometry has a navigation structure that the user can freely surf the same and, at times, such as when playing videos, the presentation is linear and sequential. Navigating the main menu - application content, useful links, scope and exit, is a non-linear navigation by allowing the user to access any buttons without any restrictions. Playback of media, videos and document (text and images) has a linear navigation structure. In the production phase, is designed, the application content (animations, still images and text) on the organization of space, point, line and plan and the multimedia application, as seen in Figure 1.

![Figure 1: Environment After Effects - Producing animations](image)

The application was developed in MO PowerPoint application in version 13. They took part in the testing and evaluation of multimedia application 68 students only in the experimental group. Students have 48 hours to use and evaluate the usability of the application using the SUS questionnaire. For Nielsen (2012), usability is defined by five quality components: i) ease of learning; ii) efficiency; iii) ease of memorization; iv) minimize errors and v) satisfaction.
We adopt the proposed Tenorio (2011 p.99) that discriminates the quality components indicated by the Nilesen questions / constituents statements SUS questionnaire, where learning facility is represented in the questions 3, 4, 7 and 10 of the SUS; efficiency by questions 5, 6 and 8; ease of memorization by 6; minimizing the error by 2 and satisfaction questions 1, 4, 9 in accordance with Figure 2 below.

<table>
<thead>
<tr>
<th>Component Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilidade de aprendizagem da aplicação multimédia (3,4,7 e 10)</td>
<td>66,91</td>
</tr>
<tr>
<td>Eficiência da aplicação multimédia (5,6 e 8)</td>
<td>76,59</td>
</tr>
<tr>
<td>Minimização dos erros da aplicação multimédia (6)</td>
<td>76,47</td>
</tr>
<tr>
<td>Facilidade de memoraização (2)</td>
<td>70,59</td>
</tr>
<tr>
<td>Satisfação dos estudantes (1, 4 e 9)</td>
<td>68,38</td>
</tr>
</tbody>
</table>

Figura 2: Componentes considerados no estudo

Therefore, only one or two of the five usability components that make up the SUS 10 questions in the questionnaire, that was / were below average fixed reference - depending on the reference value to be between 68 or 70 points. These are the components: ease of learning multimedia application with 66.91 points and student satisfaction with 68.38 points.

Main findings

Correlation between pre-test and post cards in each of sample groups

The correlation between the grades given pre- and post-test for each of sample groups (experimental and control group) aimed at assessing the existence of a linear relationship between these two variables, as seen in table 1.

Table 1: The correlation between the grades given pre- and post-test for each of sample groups

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Correlation</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 1: Note pre-test &amp; post-test score</td>
<td>Control Group</td>
<td>70</td>
<td>.919</td>
</tr>
<tr>
<td>Pair 2: Note pre-test &amp; post-test score</td>
<td>experimental group</td>
<td>68</td>
<td>.871</td>
</tr>
</tbody>
</table>

According to table 1, the correlation coefficients between the notes of the pre- and post-test for the control and experimental groups are: 0.092 and 0.087, respectively. These values indicate a strong positive correlation between the grades of pre- and post-test (for its value be above 0.7), ie, the post-test there are many students who had better grades than those obtained in the pretest against small percentage of students who got low marks achieved in the pre-test. The results are statistically significant; as p <0.05, table 1 illuestrates, which means that the correlation is strong and significant.

Conclusions and Recommendations

In this study the integration of various resources with varying capabilities and promoted complementarity between them, since the failure of one was compensated by the others.
The comparison made of rendiments diagnostic test is administered before and after the media application experiment proved to H1 whereby no difference in average scores, the yield obtained in the descriptive geometry diagnostic test between control and experimental groups using multimedia application and this is statistically significant for p <0.05, thereby rejecting the H0 hypothesis that there is equal average scores, the yield obtained in the diagnostic test of descriptive geometry between the control and experimental groups using the multimedia application. Thus, the application has improved student performance and was well received.

The potential application of aggregate multiple media becomes a concretizing feature, for starters, developing spatial visualisation ability of both required in the technical areas particularly in the very descriptive geometry.

It is suggested that given the trend of migration of applications to the cloud (internet), it is considered necessary to develop multimedia applications for learning Descriptive Geometry supported by multiple devices and available in app.

It is also recommended that multimedia application one can include more content such as those already addressed in this study (spatial organization, point, line and plane); likewise, the intersection of planes, intersection of lines with planes, projections of plane figures and geometric solids intersection, solid sections, intersecting lines with solid and solid shadows.

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PROMOTING RESEARCH-BASED INNOVATIVE BEHAVIOUR OPPORTUNITIES FOR ALL:
Inclusive, Relevant and Equitable Quality Technology Education
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ABSTRACT
Scale items related to Cognitive and Metacognitive Strategies (CMSs), Course Design Characteristics (CDCs), Knowledge Sharing Behaviour (KSB) and Innovative Behaviour (IB) can be gathered from literature and located within relevant theoretical conceptual frameworks. The purpose of the study reported on in this paper was answering the research question: How can such items be re-purposed and/or modified for measuring CMSs, CDCs, KSB and IB during technology education? The importance of this research is justified in terms of the study objectives. The paper explains the design and execution of the methodology as appropriate and adequate in relation to the research question. This quantitative research design considered issues of reliability and validity. The discussion of results shows insight and originality, suggests implications and makes recommendations that are applicable and useful. The research question is answered in the conclusion, with the conclusions being justifiable in terms of the methodology and the results of the pilot study, which allowed for refining of the measures in terms of a set of original items to be used in the main study. In this way, the pilot study reported on in this paper also contributes towards scholarly debates in the fields related to CMSs, CDCs, KSB and IB.

INTRODUCTION
Many individual items on Likert-type scales related to Cognitive and Metacognitive Strategies (CMSs), Course Design Characteristics (CDCs), Knowledge Sharing Behaviour (KSB) and Innovative Behaviour (IB) can be gathered from an extensive literature review as outlined in the latest and most relevant research findings on these topics. Applicable scales and/or items were located within a relevant theoretical conceptual framework. The purpose of the pilot study reported on in this paper was to answer the research question: How can such items be re-purposed and/or modified for measuring the effects of CMSs, CDCs and KSB on the development of innovative behaviour during technology education?

The importance of this research is justified in terms of the objectives of the pilot study, which included to measure the reliability and explore the face validity of the suggested scales, ensure that the final questionnaire was of reasonable length, increasing participation rates, and reduce the possibility of errors caused by respondent fatigue, or declining interest.
The primary risks in using this approach were that some of the measures could prove to be unreliable, reducing the number of measures per construct even further, and/or the limited number of measures might tap only a subset of a given construct.

The following section of the paper explains how the design and execution of the methodology were appropriate and adequate in relation to the research question. In this quantitative research design, issues of reliability and validity were considered. The pilot study utilised a convenience sample of 38 respondents drawn from one private university, namely Mount Kenya University. The choice of a private university was to avoid contaminating the sample population for the main study. To mitigate the risks mentioned previously, the choice of reducing the questionnaire items was made partially on the basis of face validity, to identify the most relevant measures, and partially from the results of the pilot study, in terms of factor loadings and/or additional justification. The discussion of these results shows insight and originality, suggests implications and makes recommendations that are applicable and useful.

The research question is answered in the conclusion, with the conclusions being justifiable in terms of the methodology and the results of the pilot study, which allowed for refining of the measures in terms of a set of original items to be used in the main study. In this way, the pilot study reported on in this paper also contributes towards scholarly debates in the fields related to CMSs, CDCs, KSB and innovative behaviour.

**Literature review**

**Questionnaire length**

Petersen, Louw, and Dumont (2009) commented on the aspect of questionnaire length, and posited that participants are more likely to be distracted, may skip some items, lose interest in filing the questionnaire and have less concentration, if the instrument is too long. Mowbray, Boyle and Jacobs (2014) further suggested that the questionnaire length increased respondents fatigue and subsequent response quality. Conversely, instruments that are relatively short tend to be less intimidating and respondents have a higher chance of answering all the items in the scale in full. To make the questionnaire acceptable to respondents, by them taking an acceptable amount of time to complete the questionnaire, and retain all the exogenous and endogenous constructs, some scales were shortened, while others were designed to have a specified reduced number of items, in comparison to the full-scale measures.

**Motivated Strategies for Learning Questionnaire (MSLQ)**

The Motivated Strategies for Learning Questionnaire (MSLQ) has two broad scales: those related to learning strategies and motivation (Pintrich, Smith, Garcia & McKeachie, 1991, p. v). The learning strategies scales had two components, namely resource management and cognitive and
metacognitive strategies. The resource management strategies assumed the following four (4) subscales:

a) Time and study environment (8 items),
b) Effort regulation (4 items),
c) Peer learning (3 items), and
d) Help seeking (4 items).

Examples of items in the resource management strategies component include items such as “When studying for this course, I often set aside time to discuss the course material with a group of students from the class” on the ‘peer learning’ subscale. Similarly, for the ‘help seeking’ subscale, it had items such as “When I can’t understand the material in this course, I ask another student in this class for help”. From the wording of the question items, the two scales of ‘peer learning’ and ‘help seeking’ were deemed by the researcher to be associated to the mediating variable of KSB of the study reported on in this paper. Hence, the entire component of resource management strategies was not used.

**Conceptual and theoretical frameworks**

**Cognitive and Metacognitive Strategies**
The study adopted the remaining cognitive and metacognitive strategies component of the MSLQ. Informed by Pintrich et al. (1991, p. v), the cognitive and metacognitive strategies component had 31 items, as follows:

a) Rehearsal (4 items),
b) Elaboration (6 items),
c) Organisation (4 items),
d) Critical thinking (5 items), and
e) Metacognitive self-regulation (12 items).

The original cognitive and metacognitive strategies component had the items arranged so as to mix up the questionnaire items across the subscales, and the same order was retained. There was no change made to the cognitive and metacognitive strategies component and all 31 items in the scale were retained.

**Course Design Characteristics (CDCs)**
Innovative behaviour has been correlated with job design (Battistelli, Montani, & Odoardi, 2013). Dwivedula, Bredillet, and Müller (2017, p. 609) compiled a comprehensive review of literature on job design. In their theoretical lenses review, they conceptualized work motivation in temporary organisations, by utilizing the job design perspective. The review identified “various facets of job design that constitute motivating nature of work”. Morgeson and Humphrey (2006) developed
and validated the Work Design Questionnaire (WDQ) as a comprehensive measure for assessing work design and the nature of work. The task characteristic of autonomy has received great attention in literature on motivational work design (Battistelli et al., 2013; Parker, Van den Broeck & Holman, 2017).

The motivation scales of the MSLQ questionnaire had three (3) components, namely value, expectancy, and affective. Some items in the motivation scales were deemed by the researcher to be closely related to the task characteristics subscale of the CDCs scale. For instance, the Task Value subscale had items such as “I think the course material in this class is useful for me to learn”, which closely relates to the task characteristics subscale of the present research. Hence, the Motivation scales were not used as a subscale. There may be a need for further research to explore the relationship between these variables of the motivational scales and the task characteristics subscale used in the present research.

Further information on rethinking teaching and learning in the 21st century in terms of course design characteristics towards innovative behaviour can be found in Goosen and Ngugi (2018).

**Knowledge Sharing Behaviour (KSB)**
Recent studies, which have examined the concept of Knowledge Sharing Behaviour (KSB), include Tjøflåt, Razaonandrianina, Karlsen and Hansen (2017), as well as Yi (2009). The latter author conceptualized in tabular form a comparison of the four (4) components of knowledge sharing behaviour and highlighted the associated types of channel used and the type of knowledge involved. These four (4) components of KSB in this study are hypothesized to act as mediators of IB individually and collectively.

**Innovative behaviour**
The Kleysen and Street (2001) scale had been used extensively in research on innovative behaviour (Sethibe & Steyn, 2017; Li & Hsu, 2017). The scale used in this study was based on that of Hartjes (2010), who used a case study to investigate the alignment of employee competences with the organizational innovation strategy.

**Research methodology**

**Data analysis**
Data analysis involved the preliminary stages of data entry, exploration and screening by examination of the “outliers, independence of errors, absence of multicollinearity, normality, linearity, and homoscedasticity of residuals”, as recommended by Su, Cuskelny, Gilmore, and Sullivan (2017, p. 1178). These preliminary stages of data analysis should include checking for data abnormalities that may lead to inaccurate analysis. This involves diagnosis and correcting for problems of missing data, outliers, multicollinearity, and violations of statistical assumptions before applying statistical procedures (Schreiber, 2017). The first step in checking the accuracy of the input involved an
exploration of the range (minimum and maximum) values, as well as an examination of whether the means and standard deviations were plausible (Schreiber, 2017). Studies on innovative behaviour have also explored Common Method Bias (CMB) with variables such as organisational climate (Shanker, Bhanugopan, Van der Heijden, & Farrell, 2017).

Reliability

During the piloting stage, with the aid of scale reduction techniques, some of the items with low item-to-total correlation were eliminated to minimise the number of items in each construct. However, the reduction in the number of items exposed the scale to some risks. According to Creswell (2014), the reduction in the number of items may have an influence on the psychometric properties of the scale, and its reliability. In effect, the test length is more likely to increase the magnitude of the reliability coefficient. Thus, to obtain optimal test length, a careful balance was made between time required and content issues.

The scale reduction analysis was used to generate the inter-item total correlation, and the Cronbach alpha reliability coefficients, as presented in Ngugi and Goosen (2017, 2018). This paper further reports on the items deleted, based on these reliability scores.

One way of reducing the number of items in a variable is an examination of the item-total correlation. All four of the scales, as well as the two subscales indicated, had acceptable Cronbach alpha reliability coefficients, as they were above the cut-off value of 0.7. A cut off criteria for the item-total correlations was set at > 0.3, but this rule was relaxed where the application of the rule would result in leaving only one item a subscale.

Although the reliability analysis for the innovative behaviour scale showed that it was reliable and had met the cut off criteria of internal consistency reliability value of 0.7, some of the items (3, 7, 8 and 9) had low item-total correlations, below 0.3. A closer examination of the items revealed the need to reword the items. The new item was thus reworded as follows “...pay attention to non-routine issues related to my project in software development”. The scale for IB had only 2-3 items per variable, which was acceptable. The latter scale was therefore not reduced.

The reliability analysis for the knowledge sharing behaviour scale showed low values for item-total correlation, demanding that items 1, 2 and 3 be deleted.

The reliability analysis for the task characteristics subscale showed that five items (1, 4, 6, 14 and 17) had item-total correlations below 0.25 and these were excluded from the study. Although items 2 and 3 also had low item-total correlations, they were retained, as their low item-to-total correlation was thought to be related to the reverse wording in the questionnaire items. Removal of the negatively correlated item 1 was expected to resolve problems in measurement of the autonomy subscale of the task characteristics subscale. The item “The project work is arranged so that I can do a complete piece of work from beginning to end” was also deleted, as it had an item-total correlation
of 0.295 and was similar in meaning to item “The project work involves completing a piece of work that has an obvious beginning and end”.

Finally, the item “The project work requires that I only do one task or activity at a time” was also deleted.

The reliability analysis for the knowledge characteristics subscale showed that six (6) items had very low item-total correlations and these were recommended for exclusion from the questionnaire. In addition, two (2) of the items “The project work requires a variety of skills” and “The project work requires me to utilize a variety of different skills” were similar in meaning.

During the piloting stage, verbal discussion with the respondents suggested that the questionnaire length was intimidating, as it was too long and had several similar question items that appeared repetitive. Based on an examination of the item-to-total correlations values, the final questionnaire items were reduced. In addition, in order to enhance the content validity, academic staff in Computer Science programmes were requested to judge how well the items were a true representation of the principal constructs.

**Discussion of the Findings**

Based on the information gathered during the piloting stage, it was noted that some the subscales had too many items, and/or some, which were repetitive. One critical case was three of the subscales of KSB, which had eight (8) or 7 (seven) items respectively. Similarly, the course design characteristics scale had a total of 44 items, from the two subscales of task and knowledge characteristics.

These final items were selected based on content and face validity, as well as items highlighted by low and/or negative scores for item-to-total correlation scores. This had the effect of increasing the quality of responses and the completion of items significantly. Furthermore, the questionnaire items were presented on two A4 size papers that were printed on both sides, so as not to intimidate respondents.

During the pilot, each the four (4) KSB sub-constructs had five (5) items each. The reduction in the number of items from 20 to 16 represented a decrease of 25%, which was significant.

The reduction in the number of task characteristics items from 24 to 17 represented a decrease of 29.2%, which was significant. After the pilot, the autonomy section had six (6) items, composed from Scheduling Autonomy, Decision-Making Autonomy, and Methods Autonomy. The other sections had either two (2) or three (3) items each.
The reduction in the number of knowledge characteristics items from 20 to 12 represented a decrease of 35%, which was significant. The Complexity and Information Processing sections had items reduced from eight to four (50%).

Conclusions

The research question is answered in this conclusion, with the conclusions being justifiable in terms of the results of the pilot study, which allowed for refining of the measures in terms of a set of original items to be used in the main study: The four latent variables of the study ended up containing 88 Likert scale question items, which respondents were requested to answer, categorised into four (4) Likert scales. In terms of the justification of the methodology used, the most important concern and challenge was how to increase the response rate of the respondents, by a meticulous examination of the questionnaire length and the total time required to answer the items. In this way, the pilot study reported on in this paper also contributes towards scholarly debates in the fields related to CMSs, CDCs, KSB and innovative behaviour.

References


The use of Information and Communication Technologies (ICTs) in the teaching of Natural Sciences has become a critical area of research. When trying to understand the role of ICTs in school education focusing on factors that prevent successful integration of ICTs in education is just as important as factors that allow for the use of ICTs (Bingimlas, 2009). These barriers could be related to resources, the skills and levels of training available to teachers who use ICTs, personal beliefs of teachers who use ICT in their teaching, institutional and cultural factors, as well as other factors which may influence the use of ICT in education (Blignaut, Hinostroza, Els, & Brun, 2010; Cox, Cox, & Preston, 2000). The literature also adds that the having the necessary equipment and infrastructure are often not enough to integrate ICTs in teaching rather it is strongly dependent on teachers' skills and its use in classroom activities (Elemam, 2016).

While research on barriers to the use of ICTs in teaching exist, studies on teachers’ perceived barriers in ICT rich environments are rare. The most common barrier identified by teachers in preventing them from using ICTs in teaching is the lack of resources, however when resources are available ICTs are still not effectively integrated into teaching.

This study explores a key factor perceived by three purposefully selected, junior secondary Natural Sciences teachers that limit their use of ICTs in teaching Natural Sciences. This study was conducted in an urban ICT well-resourced public school and focused on challenges faced on the use of ICTs in Natural Sciences in the light of teachers’ Technological Pedagogical and Content Knowledge (TPACK) (Koehler, Mishra, Akcaoglu, & Rosenberg, 2013). A qualitative case study approach was used and data were collected using questionnaires, lesson observations and semi-structured interviews. The interviews and the lesson observations were recorded and transcribed in full. The analysis of data involved coding and thematic categorization.

Results indicate that while ICT resources were easily available, other barriers were reported that stifled maximizing ICT pedagogical effectiveness.

A key barrier identified by the teachers revolved around learner perceptions and attitudes. Learners were reported to misuse their electronic devices in classes often at the expense of their study. The same applies to home use where learners may engage in social activities online instead of focusing on their studies. Miss Kyle, a recently qualified teacher, mentioned that the learners do not benefit
educationally from using their electronic devices, instead they spent their time engaging in social activities. Learners do not associate tablets, smart phones and other portable electronic devices as tools for learning.

Teachers believe that, to learners, electronic devices are tools for socialising and find it difficult to accept that these tools can be used for learning. When given the opportunity to use the devices learners often abuse the privilege. During the lessons observed learners had to be reminded several times to remain on track and focus on the lesson.

Interactive lessons planned around online simulations have in some cases had to be abandoned due to learners having lost log-in details. While support in the form of an IT manager was available, this often led to delays and inevitably in teachers being forced to adapt or abandon planned lessons. In cases where electronic devices were required for lessons, it is important to note that learners were reminded in advance. This meant that they would have had the opportunity to fix connectivity issues before the lesson.

Teachers indicated that they had difficulty in managing the use of learner’s electronic devices. Teachers suggested that the school should invest in monitoring programs or firewalls. In this way the teacher would be able to allow learners to use the devices in class and ensure that the learners were involved in constructive work. The difficulty expressed by teachers in managing the use of electronic devices like tablets was that unless the teacher physically moved around the class, it was difficult to observe what the learners were doing and hence the need for monitoring software. Mikre (2011) concurs with the teachers and argues that if ICTs are not used and managed properly, the advantages will be overshadowed by the disadvantages. Learners may become confused by the vast amount of information available and teachers may have trouble keeping learners on task and focused on the learning content.

In order for ICTs to be used effectively for teaching it needs to be repurposed (Chapman, Garrett, & Mählck, 2004). Learners will need to see it as a tool for education rather than something they can use to keep in contact with their friends or to play games on. It was argued that to repurpose it takes time and discipline. It requires adapting and changing.

There was also a belief that ICTs were not being used across all lessons and this made it difficult for learners to adapt to its use as an educational resource. In addition, according to the teachers, learners believe that the role of the teacher is to entertain and that therefore ICTs should be used to support that role.

There is the perception by the teachers that since software is available for almost every type of project learners have to do, they lose valuable skills by relying on the software. One of the key skills identified was the ability to analyse and think critically. Learners were believed to be unintentionally encouraged to develop lower order skills due to the type of methods being used to integrate ICT.
Technology has also conditioned learners into getting instant answers without having to do much thinking. Answers to questions can be obtained within a matter of seconds by simply going online. Teachers deem this to be unacceptable since the purpose of science education is to develop critical thinkers and “instant gratification” involves minimal cognitive skills.

Incidences of plagiarism were also reported to have increased due to the availability of ICT resources. School projects were sometimes a collection of paragraphs and pictures that were "cut and paste" together. Teachers did admit that if the projects were structured differently (by making it more interpretative or analytical rather than merely obtaining content) it would reduce the possibility of plagiarism. While it is a problem teachers do not actively look for instances of plagiarism (Khoza, 2015).

The findings of the study suggest that although teachers were eager and enthusiastic about the use of ICTs, learner perceptions and attitudes hindered the use of ICTs in teaching and learning. Teachers reported that learners viewed ICT resources as tools for socialising and gaming and therefore these resources had very little educational value to them. Monitoring of the use of these resources was time consuming and frustrating. Teachers suggested that ICTs negatively affected learners' ability to develop higher order cognitive skills since information was readily available online however teachers agreed that if tasks were structured differently learners could be more actively involved.

References


THE EFFECTS OF 3D SOLID MODELLING ACTIVITIES ON SPATIAL VISUALISATION SKILLS OF GRAPHIC DESIGN STUDENT TEACHERS

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Abstract

The current research focused on the effect of Three-Dimensional Solid Modelling (3DSM) on the spatial visualisation skills (SVS) of first year student teachers in a graphics design module. Underpinned by Piaget's perception and imagery theory the study evaluated the impact of a 3DSM intervention on students’ SVS. The study was carried out at the University of ABC (ABC) comprising 200 pre-service graphics design student teachers. Guided by the objectives of the study and a pre-test-post-test control-group design, the study employed the Purdue Spatial Visualisation Test (PSVT) to evaluate students’ SVS before and after a 3DSM intervention. Findings showed that there was a statistically significant difference with a moderate positive effect in the SVS between the experimental group and the control group. Therefore, the use of 3DSM software can be considered as an instructional methodology in a graphics design module.

Keywords: Spatial visualisation, 3D solid modelling, Piagets’ Perception and Imagery Theory

Introduction

The current study explored why graphic design students struggle to convert multi-faceted objects from orthographic (2D) into isometric (3D). Sufficient work already showed a well-established link between graphic design and SVS (Alqahtani, 2017). Research indicate that SVS is an important human skill, a vital trait in human intelligence and fundamentally important in engineering and technology fields (Rodriguez & Rodriguez, 2016). Furthermore, several studies report that 3D computer assisted design has a strong positive correlation to increased SVS (Fleisig, Robertson, & Spence, 2011). In addition, 3DSM software, such as “SketchUp”, showed positive impact on improving SVS (Ligocki, 2011). With this in mind, the study first evaluated students’ SVS and secondly it examined the effect of 3DSM on SVS.

Spatial visualisation

There is consensus in literature that SVS is one of three factors of spatial ability, the other two being spatial perception and mental rotation (Kösa & Karakuş, 2017). According to Rafi, Anuar, Samad, Hayati and Mahadzir (2005), spatial ability is the ability to mentally manipulate or transform the image of spatial patterns into other arrangements. On the other hand, SVS is the ability to imagine
the rotation of depicted objects, the folding or unfolding of flat patterns and the relative changes in position of an object in space (Koch, 2006). Friess, Martin, Esparragoza and Lawanto (2016) conclude that SVS is the ability to manipulate an object in an imaginary 3D space. Furthermore, Kösa and Karakuş (2017), state that SVS is the ability to imagine the manipulations of objects mentally; this requires the mental rotation of 2D or 3D objects in space. Likewise, Duffy, Sorby and Bowe (2016) agree that SVS are important particularly in the fields of engineering, graphics, and other scientific courses.

**Three-dimensional solid modelling**

3DSM is the representation of the solid parts of an object on computer (Kurtuluş & Uygan, 2010). A geometric model is made up of “wire frames” that show the object in the form of wires. This “wire frame structure” can be 2D or 3D and can provide surface representation to the wire thus giving 3D views of geometric models which makes the object appear solid on the computer screen (Hsu, 2010). Hsu (2010) describe parametric modelling as a type of 3DSM where the parameters of the model, such as dimensions, may be modified to change its geometry. When for instance a dimension is changed, the geometry of the model is updated, thus, the parameter drives the geometry (Hsu, 2010). The current research used the 3DSM software “SketchUp”. Martín-Dorta et al. (2008) suggest that SketchUp is a good option to use in graphics design for improving spatial skills because of several advantages such as; “being freely downloadable from the internet, easy to learn and, it combines a simple robust tool-set with an intelligent drawing system”.

**Theoretical Framework**

The cornerstone of this study was Piaget’s perception and imagery theory. Potter and Van der Merwe (2001) indicate that Piaget’s theory comprises four stages of perception, namely, (1) sensori-motor, (2) pre-operations, (3) concrete-operations and (4) formal-operational. Makgato and Khoza (2016) essentiate these four stages for students’ perception and visualisation in engineering graphics. Two important stages to the current study are the concrete-operational, during which a person can perform reversible mental actions on concrete objects and; formal-operational, where persons can classify, order and reverse mental operations and are capable of abstract reasoning.

**Methodology**

The current study employed a randomised experimental pre-test-post-test control group design. The control group was randomly selected from a cohort of 250 students enrolled for a graphics design module at ABC in 2016. The experimental group was randomly selected from a cohort of 250 students enrolled for the same module in 2017. The pre-test was administered to both groups at the start of the module. The control group followed conventional instructional methodology including sketching and drawing activities. The experimental group received 3DSM intervention.
Instrument

The PSVT: Visualisation of Rotations (PSVT:R) was used to measure SVS. The PSVT:R is mainly used to assess SVS in educational settings such as graphic design (Kösa & Karakuş, 2017). The PSVT:R shows a criterion object and a view of the same object after undergoing a rotation. Students are then shown a second object and asked to indicate what the view of that object would be if the second object were rotated by the same amount in space.

Findings

Post-intervention findings showed the means of the PSVT:R post-test for both the experimental group (M = 54.7) and the control group (M = 47.9) increased. ANCOVA showed a statistically significant difference between the groups on the post-intervention PSVT:R scores, F(1, 197) = 13.14, p = .000, partial eta squared = .063. Findings showed a strong relationship between the pre-intervention PSVT:R scores and the post-intervention PSVT:R scores as indicated by the partial eta squared value of .365.

Conclusion

There was sufficient evidence that graphics design students from ABC experienced problems such as the inability to visualise multifaceted 3D objects from their 2D views. The ability to create a 3D mental image of an object from its underlying 2D views is to a large extent dependent on SVS. In turn, and grounded in Piaget’s perception and imagery theory, SVS is acquired through active participation in spatial activities of which coping and sketching forms the basis. Furthermore, various international studies have proven that students’ SVS could be improved by among others 3DSM. Hence, this study endeavoured to determine whether the 3DSM would have any effect on students’ SVS. The 3DSM software in this study was SketchUp because it enables students to build and modify 3D models quickly and easily. The study used randomised experimental pre-test-post-test control group design with a 4-week 3DSM intervention. SVS was assessed by the PSVT:R before and after the intervention. Findings showed a statistically significant difference with a moderate positive effect in SVS between the experimental group and the control group. Therefore, the use of 3DSM software can be considered as an instructional methodology in graphics design.

References


The purpose of this study was to investigate the manner in which learners integrate scientific knowledge in technical education through technical sciences. The Department of Basic Education (DBE) has recently introduced technical sciences as a new subject to support learners in three areas of technical education, namely mechanical technology, electrical technology, and civil technology (DBE, 2014:9). Technical sciences is intended to enable learners to integrate scientific knowledge in a more informed way in the subjects that are technology related. The subject exposes learners to scientific concepts and skills that have relevance to technical orientation in schooling. Most importantly, the subject aims to address the needs of the industry (mechanical, electrical, and civil) and the technical education in order to promote technology in the technical schools.

Mechanical technology focuses on concepts and principles in the mechanical environment and on the technological processes (DBE, 2011a). Electrical technology focuses on the understanding and application of electrical and electronic principles (DBE, 2011b). Civil technology focuses on concepts and principles in the built environment and on the technological processes (DBE, 2011c). In addition, mechanical and civil technology aim to create practical skills and the application of scientific principles. The latter subjects intend to create and improve the engineering, manufacturing, and built environment in order to enhance the quality of life of the individual and society and to ensure the sustainable use of natural environment. Technical sciences focus on six main knowledge areas, namely mechanics; matter and materials; electricity and magnetism; waves, sound and light; heat and thermodynamics; and chemical change. In addition, learners are required to do practical work that must be integrated with theory in order to strengthen the concepts being taught (DBE, 2014).

According to Lederman, Lederman and Antink (2013), the nature of scientific knowledge is frequently expressed as the ‘nature of science’ and different views of how scientific knowledge is established are related to scientific inquiry. Learners should be mindful of the essential differences between observations and inference, and between scientific laws and theories. However, the nature of technological knowledge is based on procedural knowledge and conceptual knowledge. Procedural knowledge is referred to as the ‘know how’ while conceptual knowledge is referred to as ‘knowing that’ (McCormick, 2004).

The introduction of technical sciences support learners to apply the specific science concepts into technical education subjects. Previously learners studied physical science without being
knowledgeable on how the specific physical science concepts can be used to determine technological solutions. However, technical sciences was introduced as a relevant subject without appropriate training for teachers. This is the same mistake that the government authorities committed when introducing technology education. In addition, no research has been conducted in South Africa to determine the effectiveness of technical sciences. This study is the first to prepare the basis for further research.

Practical Assessment Task (PAT) was used as a framework to determine the way in which learners integrate scientific knowledge in mechanical technology, electrical technology, and civil technology. PAT involves the aspects of investigating, designing, making, evaluating, and communicating – (IDMEC). This study engaged in qualitative research using multiple case study design as described by Ary, Jacobs and Sorensen (2010). Purposive sampling was used to identify the participants. Six groups of learners in three schools in different technology subjects were selected as participants. Data was collected by means of documents and interviews. Documents refers to activities given to learners and examination final papers. Learners were interviewed on how they integrated scientific knowledge when building the projects. Data was analysed using cross-case analysis strategy (Johnson & Christen, 2008).

The research findings revealed that the sampled learners are to a certain degree able to integrate scientific knowledge into technical education subjects. However, some learners mentioned that they find the subject very difficult to understand. The study recommends that teachers be supported to develop pedagogical strategies so that they are able to support learners to comprehend and link the procedural knowledge with the conceptual knowledge. Scientific knowledge in technical science empower learners to understand the relevant technological concepts and apply them appropriately.

List of references


THE TECHNOLOGICAL LITERACY OF FIRST YEAR UNIVERSITY STUDENTS AT TWO HEI’s IN THE WESTERN CAPE PROVINCE AND THE INFLUENCES OF SES

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In this study, the technological literacy of learners at the end of their schooling are described, analysed and compared. The study further investigates the possible influences of socio-economic status (SES) on technological literacy in a unique group of engineering students. The study will use a mixed-method approach applying the sequential use of both quantitative and qualitative data collection. During the quantitative data collection phase, a valid and reliable instrument, the Technological Inventory Profile (TIP) will be used to determine the students’ levels of technological literacy. The sites of the study are two higher education institutions (HEI’s) in the Western Cape Province. Students were chosen in the Western Cape Province since it is believed that a diversity of students entering university will be drawn from schools with varying SES backgrounds. During the qualitative data collection phase, the profiles of two students from high SES and two from low SES backgrounds who entered an Engineering programme will be probed through a case study approach. Students’ background, described in terms of their home and schooling, will be probed, to determine patterns and trends that shaped their levels of technological literacy up to the point of university entry.

BACKGROUND TO THE STUDY

In the 21st century, countries around the world require a workforce highly knowledgeable of current technologies to develop a viable economy. South African policymakers along with international trends recognised the role of technology by establishing a school curriculum to promote technological literacy at the end of their schooling.

South African students entering an engineering programme should have more than just a demonstrated competence in quantitative literacy. Ideally, an Engineering student should possess a high level of technological literacy – that is – have a superior conception and level of interaction with technology (Collier-Reed, 2006). This means that an Engineering student should conceive of technology as a solution to problems, and interact with technology as tinkering or engagement. But the reality of students entering Engineering programmes in South Africa is that though they might possess these skills, gaps in knowledge, imposed by constraints in their background, are not reflected in the NSC and NBT results. Indeed, background constraints, primarily their educational (schooling experiences) and home environments, which are factors that are socio-economically linked, might constrain (or strengthen) the level of influence of their technological literacy. Thus investigating these factors should be complementary to students’ technological profile, to inform the design of their
learning experiences and learning environments. Understanding these could largely impact on teachers' pedagogy, content, style, school programmes, academic development programmes at universities to guide the development of teaching for the new generation.

In this study, the technological literacy of learners at the end of their schooling are described, analysed and compared. The study further investigates the possible influences of socio-economic status (SES) on technological literacy in a unique group of engineering students. The study draws on the framework of Mitcham (1994) who describes technological literacy by two interacting components, namely, how one ‘thinks’ about technology (nature of technology) and how one interacts with technology (interaction with technology), acknowledging the socio-cultural context of an individual, where social, cultural, educational and work backgrounds influence ones understanding of technological literacy.

The study seeks to answer the following two research questions:
(1) To what extent are students technologically literate at the end of their schooling?
(2) Does the Engineering student's background, described in terms of their socio-economic status, influence their levels of technological literacy?

THEORETICAL FRAMEWORK

Recently, a holistic definition of technological literacy, comprising two components, has been argued to create a fuller picture, as it considers how individuals ‘think’ about and ‘interact with’ technology – combining thinking and doing. The work of Mitcham (1994) describes technological literacy by two interacting components, namely, how one ‘thinks’ about technology (nature of technology) and how one interacts with technology (interaction with technology). Importantly, this view acknowledges that the two components do not exist in a vacuum, but are confounded by the socio-cultural context of an individual, where social, cultural, educational and work backgrounds influence ones understanding of technological literacy (Garmire & Pearson, 2006). Through these interactions, levels of technological literacy develop. Individuals have different levels of technological literacy – ranging from simplistic to sophisticated. More recently, Collier-Reed (2006) extended the framework of Mitchum (1994) by adding a third component that unifies three major dimensions of technological literacy – the three-component model of defining technological literacy. This model describes an individual’s level of technological literacy more holistically. The three-components are knowledge (nature of technology), capabilities (interaction with technological artefacts), and critical thinking and decision-making (NRC, 1996; Garmire & Pearson, 2006; Collier-Reed, Case & Linder, 2009). These three components are argued to develop a holistic perspective of an individuals’ technological literacy, and further develops a focus on the essential levels of technological literacy. First, the knowledge dimension of technology literacy includes both factual knowledge and conceptual knowledge. Second, the capabilities dimension relates to how well a person can use technology (defined in the broadest sense) – and influences how a person solves problems during the design process. Lastly, the critical thinking dimension has to do with ones approach to technological issues.
The three-part model is commensurate with a study of Collier-Reed (2006), who defined technological literacy as “understanding the nature of technology, having a hands-on capability and capacity to interact with technological artefacts, and ... be able to think critically about issues relating to technology (Collier-Reed, 2006, p. 15), a framework and definition that will be adopted for the purpose of the present study.

METHOD

The sample for the quantitative data collection included 219 first year students at two higher education institutions (HEI’s) in the Western Cape Province where Engineering is offered. The two HEI’s draw students from different SES contexts. Although the study reported in this paper is largely qualitative, it has included important quantitative information gathering strategies as recommended by (Field, 2005).

The study will take place in two sequential data collection phases – the quantitative and qualitative data collection. This contemporary mixed-method approach is employed to triangulate the data to provide credible and trustworthy answers to research questions (Creswell, 2009). The study used a mixed-method approach applying the sequential use of both quantitative and qualitative data collection. During the quantitative data collection phase, a valid and reliable instrument, the Technological Inventory Profile (TIP) was used to determine the students’ levels of technological literacy. The instrument was developed from a previous phenomenographic study defined by the levels of technological literacy, namely, Artefact, Process, Direction/Instruction, Tinkering and Engagement. The study sites were two higher education institutions (HEI’s) in the Western Cape Province, with varying SES backgrounds. During the qualitative data collection phase, the profiles of two students from high SES and two from low SES backgrounds who entered an Engineering programme was probed through a case study approach. Students’ background, described in terms of their home and schooling, is probed, to determine patterns and trends that shaped their levels of technological literacy up to the point of university entry. The qualitative research would provide in-depth understanding of the students' levels of technological literacy. Compared to other methods, the strength of the case study method is its ability to examine, in-depth, a “case” within its “real-life” context (Yin, 2003). The choice of using the case study method depends on the research questions, and can either be descriptive or explanatory (Yin, 2014).

FINDINGS

Preliminary findings suggest that students in general have a basic level of technological literacy. The levels of technological literacy, namely, Artefact, Process, Direction/Instruction, Tinkering and Engagement were examined for the profiles of students in the sample. The study draws primarily on the qualitative case studies results and is complemented by the quantitative profiles. However, preliminary results of the qualitative part of the study shows that there is a
tentative influence of SES on the participants’ technological literacy. The study further recommends that the school curriculum must develop components where parental involvement can support students’ development of technological literacy. Such support must be structured and pedagogically-informed partnerships for both educators and parents, set in place before the learners enter high school, yet monitored through high school.

SIGNIFICANCE

This study is significant because it will put a framework in place so that the current support structures can be strengthened and be positioned appropriately to help grow South African science and engineering education. The research on first year university Engineering students at two HEI’s on their levels of technological literacy is the first of its kind in South Africa, let alone Western Cape Province and thus it is likely to open up new avenues for research and thus broaden the research base in the province. The use of a valid and reliable instrument developed in the South African context to measure levels of technological literacy is an important contribution to educators and researchers.

By critically evaluating the first-year students’ levels of technological literacy and linking it to home background, will illuminate the influence of SES on South African students’ levels of technological literacy.

This study is significant because the research report will have far-reaching implications for school and university curricula and pedagogy to improve the success rates of Engineering students at HEI’s. Recommendations from the results could also be used to improve where necessary the pedagogical approaches in preparing students for first year university programmes.

REFERENCES


IMPACT OF ICT INTEGRATION IN SCHOOLS WITH LIMITED RESOURCES: A CASE STUDY OF PHYSICAL SCIENCE TEACHERS IN GAUTENG PROVINCE, SOUTH AFRICA

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INTRODUCTION

The current era is unprecedented in terms of the advancement and application of Information and Communication Technology (ICT) in education (Ford & Botha, 2010:1). Teachers are now more than ever before, required to modify their ways of teaching in such a way that full advantage is taken of a wide range of available ICT resources. They are furthermore expected to lead the technological revolution by guiding the already technologically adept youngsters on how to optimally utilize the technologies for the benefit of their learning.

Literature has already highlighted the gap that exists between teachers and students with regards to the extent of general use of technology. Hakverdi-Can and Dana (2012:94) affirm that the use of ICT in education has been widely recommended by curriculum developers around the world. Presently, most schools in South Africa have access to some ICT resources and several Physical Sciences teachers have received training on how to integrate ICT in their teaching (SAIDE, 2010:28). It stands to question though, whether the training received by teachers has adequately prepared them to incorporate ICT in their teaching.

METHODOLOGY

2.1 Research design
A mixed methods design is a relatively new design and builds on both quantitative and qualitative approaches (Ivankova, Creswell & Clark, 2007:260). This design was utilised in this study. Quantitative data was collected through a questionnaire administered with Physical Science teachers in an effort to determine the extent to which they integrate ICT in their teaching. The data collection instrument was adapted from the Micro-computer Utilization and Teaching Efficacy Beliefs Instrument (MUTEBI) developed by Enochs in 1993 to measure usage of micro-computers in Science classes. Qualitative data was obtained through semi-structured interviews and document analysis.

2.2 Population sampling
A population is defined by White (2004:49) as all possible elements that can be included in the research. The population in this study comprised of 85 Physical Science teachers employed in Atteridgeville and Mamelodi schools in Tshwane South District. The population from which
candidates for interviews was selected comprised of purposively selected Physical Science HODs and ICT coordinators of five of the schools involved in the study. The analysed documents include sample material collected from interviewees at five different schools and they include policies, minutes and lesson plans.

Sampling is done when not all members of the population could be included in the study (Leedy & Ormrod, 2013:152). Complete or full enumeration was adopted in the study. It is a technique applied when all members of the population are given a chance to contribute information relevant to a study (Barnett, 1991:11). This technique is more relevant where the population is not too large or the type of data warrants that all members of the population be studied (Aldridge & Levine, 2001:62).

In selecting candidates for interviewing, purposive sampling was employed. The researcher employing this technique purposefully selects a particular section of the total population to include in the sample (Cohen, Manion & Morrison, 2007:110). The criterion for selection was based on performance of particular teachers, HODs and ICT coordinators.

RESULTS

Four questions were viewed by researchers as crucial in determining teachers’ competence in integrating ICT in their teaching:

- How much training was received by the teachers?
- How proficient are teachers in using ICT resources, the internet, programmes and applications?

3.1 Training received by teachers on ICT integration

Coupal (2004:589) points out that teacher training is central to the effective integration of ICT in Science education. The following pie chart gives an indication of teachers who attended training in ICT integration:

![Pie chart showing percentage of teachers trained/untrained in ICT integration](image)

*Figure 1: Percentage of teachers trained/untrained in ICT integration*

At the time of reporting, 56% of teachers in Tshwane South District at previously disadvantaged schools have received some form of training in ICT integration. This high percentage of untrained
teachers could be a contributing factor to the apathy of integration of ICT in Physical Sciences classrooms.

3.2. **Length of training in ICT integration**

The duration of training is also an important factor when it comes to acquiring the necessary skills for successful integration. The period of training was expressed in days and respondents were requested to write down the number of days of training they received. Of the 30 respondents who received training the number of days of training were nine.

It is the researchers’ opinion that nine days are adequate for teachers to learn the required skills to adequately integrate ICT in Physical Science teaching provided they attend the training, already having an intermediate to advanced level of computer literacy.

The mode of 20 implies that more teachers indicated that they attended training for 20 days. The figure below is a frequency table indicating the number of days training per number of teachers who attended.

![Figure 2: Duration of training attended](image)

3.3. **How proficient are teachers in using ICT resources?**

In determining the proficiency of ICT integration, the researchers used definitions used by SAIDE. SAIDE identified between two levels of ICT integration, which are; representational use through which the teacher simply use ICT to represent information, and generative use which is more higher in order and involve using ICT to generate knowledge.

The chart below illustrates the findings made by researchers with regards to the level of ICT use. This involves the use of physical resources and that of software and programmes:
Figure 3: Proficiency of ICT integration

25% of generative use is viewed by researchers as not sufficient. It is however noted that most teachers were introduced into the system with little or no computer literacy which then becomes a hindrance to effective integration.

When interviewing HODs and ICT coordinators it became eminent that, training of teacher on ICT integration is left much with individual schools and teachers. Attendance of training was not mandatory as no consequences were clearly stipulated for non-attendance. This could significantly slow down the potential gains of such training.

RECOMMENDATIONS FOR EFFECTIVE ICT INTEGRATION

In the light of these findings, the researchers make the following recommendations to responsible stake holders for effective ICT integration in the subject of Physical Science:

- ICT training should be intensified but geared to the computer literacy level of individual teachers
- Teachers (not only schools and learners) should be provided with ICT resources for practice and preparation at home
- ICT integration should be mandatory and included in performance measurement systems
- ICT support should be on-site

The researchers also recommend the following areas as still open for further study:

- How managers manage the implementation of ICT in their schools
- ICT integration in other districts and/or with different school types

CONCLUSIONS

The study followed a scientific mode of inquiry. Findings made, if implemented can enhance the effectiveness of ICT integration. The integration must however take into account change theory which may have severe implications in the successful integration of ICT.
A greater amount of investment must be made in teacher development in order to make the buy in by teachers possible. Investment in teachers should also include making resources available and accessible to teachers. An investment in teacher training will ensure that teachers’ fears are alleviated and thus improve the integration.

REFERENCES


Abstract

The purpose of this article is to investigate successes and challenges of integrating interactive whiteboard in secondary schools. The participants were 123 secondary school teachers who used the interactive whiteboard in teaching and learning in Gauteng, Tshwane North District. The question posed in this study is: How were interactive whiteboards integrated in teaching and learning in the secondary school? In order to answer this question qualitative case study method was used. Data were collected by means of observations and individual semi-structured interviews. Data were analysed using Atlas.ti. The findings revealed that teachers identified training, material on interactive whiteboard, consulting other resources and mentors as successes for using interactive whiteboard in the classroom. On the hand, these teachers identified technical problems, teaching and learning, learners, health hazards, training as well as security as challenges with the integration of interactive whiteboard. It is critical that sufficient and continuous professional development on the pedagogical integration of interactive whiteboard be provided rather than the technical use or operation of interactive whiteboard.

Keywords: Interactive whiteboard, successes, challenges, secondary school

Introduction

There is a massive uptake of Interactive whiteboard in high schools (Kaur, 2015; Gregorcic, Etkina & Planinsic, 2018). Research shows that in most of the countries, such as in Canada, Australia, South Auckland, United States, United Kingdom and New Zealand (Pourciau, 2014; Kaur, 2015; Fogarty, 2012; Hodge and Anderson, 2007; Hicks, 2011) high schools has followed this trend. Interactive whiteboards (IWBs) have recently gained attention in South Africa particularly in Gauteng province. The Member of the Executive Council (MEC) for Education in Gauteng introduced the tablets and smart classrooms in Gauteng public schools (Lesufi, 2014). In this regard, most of the teachers in secondary schools used IWBs in the classroom.

It is pointed out that the IWBs in schools improves the whole-class teaching as it adds visual impact and interactivity in the lessons’ (Gregorcic, et al., 2018). Teachers has a potential to open up all resources needed for a particular topic on the screen. The positive effects of IWBs depends on how teachers use them (Türel & Johnson, 2012). This author, indicated that IWBs helped teachers draw
the attention of learners and facilitate learner retention and understanding of concepts. Furthermore, IWBs provides time efficiency during teaching and are motivating, engaging, and enjoyable for both teachers and learners.

Teacher professional development plays a vital role in the implementation of innovative technologies in the teaching and learning environments. In fact, Pourciau (2014) argues that professional development should be teacher-driven so that it provides the necessary support for proper implementation. Proper implementation of IWB would allow teachers to gain innovative knowledge, skills as well as remain life-long learners in the area of technology (Hicks, 2011).

In South Australian public and independent secondary schools, purchased and installed interactive whiteboards in the classrooms without really knowing how they would impact on students' learning (Kaur, 2015). The study conducted by Pourciau (2014) revealed that at Berry Middle school, teacher also have this IWBs, but the challenge was that teachers did not use this technology to enhance the teaching and learning. The reason for this was the lack of adequate training of teachers to use the tool (Pourciau, 2014).

This article reports on successes and challenges of integrating interactive whiteboard in secondary schools. In order to do this, firstly the researcher observed lessons where teachers used the IWB in the classroom. The researcher completed the observation sheet. Secondly, semi-structured interviews were conducted with teachers who used the IWB in teaching and learning. The aim was to determine the successes and the challenges that were encountered during the integration of IWBs in various subjects in secondary schools.

Literature review

The use of interactive whiteboard in teaching and learning

The efficacy of IWBs in teaching and learning increase motivation and task engagement on the learners (Hodge & Anderson, 2007). IWBs allows the learners to control objects on the screen through touch, and they can be linked to classroom computers and tablet devices (Kaur, 2015). In the study conducted in Canada at Riverview High School in Riverview, New Brunswick, results showed that using the IWBs as a collaborative tool in teaching and learning encouraged discussion between learners, promoted engagement and interactive, increased student learning and encouraged learner-centred (Fogarty, 2012).

Professional development on the use of interactive whiteboard

The effective use of IWBs requires teachers to understand the methods of interactive teaching (Alghamdi & Higgins, 2015). Consequently, this need more appropriate teachers continuing professional development to ensure their growth and improvement in the use of IWB. In this regard, teachers need to be trained on how to use the interactive features of an IWB (Karsenti, 2016).
**Teacher perception on the use of IWB**

It is reported that teacher’s confidence in the mastery of the IWB plays an important role in the teacher’s willingness to transfer activities within the lesson to the learner’s setup (Gregorcic, et al., 2018). In the study conducted by Karsenti (2016) in Canada, teachers’ perceived IWB as a complicated technology.

**Successes of using IWBs in teaching and learning**

In the study conducted by Olelewe & Okwor (2017) in Enugu State, Nigeria it was reported that about 61% of teachers felt that IWBs were successful as it made them active in their teaching practices. Furthermore, their results also revealed that the majority of lecturers (68%) perceived IWBs as a relevant Information and Communication Technologies tool for teaching and learning (Olelewe & Okwor, 2017). Karsenti (2016) indicated that IWBs are useful and positive education technology tool. The powerful potential of IWBs as a presentation tool is that it assists the teachers to present more than one resource in the lesson and more efficiently (Gregorcic, et al., 2018). Furthermore, it allows teachers to use face-to-face teaching and computer-aided learning more efficiently (Al-Faki & Khamis 2014). IWBs, reduce workload for teachers as it enables them to share and reuse materials. In this case IWB serve as a motivational tool to teachers to transform their teaching strategies, thereby seeking professional development (Gregorcic, et al., 2018).

**Challenges of integrating IWB in teaching and learning**

Literature revealed the challenged that were encountered by teachers with the integration of IWB include ineffective training methods, difficulties understanding training, inability to travel after school hours to training workshops, teachers do not want to attend workshops, lack of adequate funding for the purchase of additional equipment and lack of follow-ups sessions to help with the IWBs in schools as well as the lack of on-going training (Pourciau, 2014). For effective utilisation of IWBs (Olelewe & Okwor, 2017) reported that the use of IWBs were found to be grossly lacking due to lack of institutional support and inadequate power supply.

**Research question**

How were interactive whiteboards integrated in teaching and learning in the secondary school? In order to answer the research question, sub-questions were formulated. These sub-questions were:

- What were teacher successes of integrating interactive whiteboard in the classroom?
- What were the challenges of encountered by the teachers in implementing interactive whiteboard?

**Method**

A qualitative case study method was used in this study. A qualitative case study provides an in-depth study of this system based on a diverse array of data collection materials, and the researcher situates this system or case within its larger context or setting (Creswell, 2007, p. 244). In this study the case
were 27 teachers and the settings were Secondary schools in Tshwane North, Gauteng District in South Africa. Data were collected by means of observations and individual semi-structured interviews. Data were analysed using Atlas.ti. In analyzing data the hermeneutic unit called smartboard project was created which consisted of two primary documents. primary document 1 was the data collected for observations and primary document 2 were data gathered from the semi structured interviews. From these documents, 366 codes were highlighted and the system generated 415 quotations which were grouped into 14 conceptual networks. Figure 1 show the Primary documents

Participants
In this study a purposeful and convenience sampling were used to select participants. The researcher observed five schools from which three participants were male and four were females. For purposes of the interview, participants were 20 teachers from 20 secondary schools in Tshwane North District, South Africa. In all, 27 participants participated in this study.

Instruments and Procedure
The observation tool consisted of three questions. The role of the researcher in this regard was that of a non-participant observer. The researcher observed five secondary schools where teachers used IWB/ during the lesson. During the observations, the researcher did not interfere with normal running of school programmes or the teaching proceedings in the classroom. The researcher completed the observation tool without asking questions.

Individual semi-structured were conducted by the researcher. The interviews were recorded using a smart phone. Participants had to respond to three questions such as “Did you receive training on the
use of IWB? How do you use IWB in class”? Issues of trustworthiness were ascertained based on dependability and objectivity. In this study dependability was ascertained when the research instruments were made available to study University of Technology ethics committee, Gauteng Department of Education and the participants signed the consent letters. Objectivity was guaranteed when the researcher discussed the study objectives with the supervisor. The interview transcripts data were discussed with the participants for them to verify if what was interpreted is what they meant. Furthermore, the researcher verified the codes with the experienced researcher who had access to Atlas.ti 6.2 before networks were created.

Findings

Observations
From the observation tool, three conceptual networks were created relating to teacher use of IWB in the class, efficacy of IWB and IWB challenges. In Question 1, the researcher focused on how teachers used IWB during the lessons? In this case, thirteen themes were created from this category. The researcher observed teacher Mofokeng using the IWB as a writing board. He further observers Teacher Maphalala and Moloi writing on the screen using their fingers. Concerning theme 3, display loaded textbook; Teacher Moloi loaded and displayed textbook on the IWB. Teacher Radebe loaded and display textbook by page number and learners read from the screen. About PowerPoint presentation; Teacher Mofokeng used the USB to load a presentation on the IWB USB port the presentation displayed on the IWB and he taught from there. With regard teacher-centred approach, Teacher Nkomo used the teacher-centred approach. She instructed learners to follow her lead, learners were not participating in the lesson. The lesson was teacher-controlled. Concerning observation theme 6; cannot use IWB, Teacher Nkomo was not properly equipped to use the IWB, she only displayed the topic of the lesson. She struggled a lot to connect the presentation. It was a challenge for him to use the IWB. He reverted to the white board which was next to the IWB.

In Question 2, the researcher focused on efficiency of the teachers in using the IWB in presenting the lesson. Here, 2 themes that related to the category of effecting use of IWB and confidence emerged. In terms of effective teaching using IWB; the researcher discovered that most of the teachers used IWB effectively for PowerPoint presentations. Some of the Teachers seemed to master some features of the IWB. With regard to, the confidence or self-esteem of the teachers; the researcher discovered that teacher Mofokeng was limited to what he has on the USB, but seems confident when presenting the lesson. On the other hand, Teacher Nkomo was not properly equipped to use the IWB, she lacked confidence in the use of IWB in the classroom. She avoided questions from the learners. She did not use the IWB optimally. Teacher Nkomo seemed to have trust and confidence in the textbook rather than the IWB.

In Question 3, the researcher focused on the challenges encountered by teachers during the lesson when using IWB? Here, 15 themes that related to the category of IWB challenges were generated. In this case, the researcher observed Teacher Maphalala using the IWB and it got stuck in the middle of
the lesson. He then switched it off and restarted it. When teacher Mofokeng began the lesson, the researcher observed the IWB took time to load information. When teacher Maphalala wanted to use audio from the lesson presented on the IWB, the could not operate the audio enhancement of the IWB.

**Semi structured interviews**

In Question 1, teachers were asked to respond verbally to the question about the training they received on the use of IWB. Yes/No elaborate on the training. Here, four themes emerged that that related to the category yes, I received IWB training, not enough, duration, and days. Figure 2 shows the conceptual network relating to IWB training.

![Figure 2: The conceptual network relating to IWB training](image)

Teacher Mooka and Teacher Zwane said, ‘Yes, we received training’. Teacher Aphane indicated that ‘You know ICT needs enough training. The type of training that was for 5 hours is not enough’. Teacher Dube revealed that ‘We use to have classes or meet every Wednesday to familiarise ourselves with a Smartboard’. Teacher Baloyi indicated that, “It frustrates me sometimes because I need to do some of the things but I cannot because I think I am not well trained to be able to use it effectively in my lessons”. In terms of the duration; Teacher Khosi responded, “three months” and that “and they run the training in the afternoon”. Teacher Sepeng said, “We did receive training normally after school maybe twice a week”.

In Question 2 of semi-structured interviews, teachers responded verbally to the question about the smart-board containing the materials that assisted them in doing lesson preparations and assessments? In this instance, eleven themes emerged related to yes IWB contain materials; represent charts; diagrams; textbook; videos; project; experiments; projective lessons; show projective lessons; Life orientation; and no materials. Figure 3 shows the conceptual network
relating to IWB contain teaching and learning material. Teacher Zelda said ‘Yes Sir, even the books are there and the assessment are there in the books’. Teacher Duma indicated that ‘The material that is there is only the textbook for learners’. Teacher Sammy said ‘I use it for projective lessons, videos and experiments’. Teacher Akani said ‘The smartboard currently does not have what I need so I am preparing at home so that I can use it on smartboard’.

Figure 3: The conceptual network relating to IWB contain teaching and learning material

In Question 3, teachers were asked to describe the challenges they experience from the optimal use of the IWBS. In this case the category that emerged was named IWB challenges. This category had fifteen themes related to IWB does not contain vernacular materials; IWB affects eyes; no signal sometimes; cannot interact with learners; lack of audio enhancement; cannot link with tablets; cannot draw graphs; cannot add information; takes time; not used to IWB; no electricity; lack of internet connection; security; learners did not finish writing; and shuts down. Figure 4 shows

Figure 3: The conceptual network relating to IWB challenges
Teacher Smith said “Maybe I can talk about my life. The smartboard light is affecting my eyes every”. Teacher Daniel responded ‘sometimes when you reopen it, it takes long then you lose certain minutes on your teaching’. Teacher Peters indicated that ‘It needs to be orientated because sometimes it gets stuck and then it is time consuming, maybe you have 30 minutes lesson then you have to resort to the chart or the chalkboard’. Teacher Zack said ‘That is when we get a challenge and then the other one is that I am not used to IWB for now’.

Discussion

It may be observed for the findings that most the teachers successfully used IWB during the lesson. The manner in which teachers used the IWB differs. In this study, most of the teachers used IWB as a writing board using their own hands. This finding is similar to the one reported by (Kaur, 2015) that even learners used their hands to interact with the material on the smartboard. Teachers made use of the textbook which was uploaded on the IWB to conduct the lesson. In this case, the learners were able to read from the board. Gregorcic, et al. (2018) argue that IWB allow teacher to reuse materials which reduce the workload. Teachers were able to use other devices such as laptop and USB together with the IWB. This shows that these teachers were well equipped to use the IWB. It may be argued from this study that teacher effectively used the IWB with PowerPoint presentations. They mastered most of the functionality of the IWB. It was found in this study that most of the teachers were confident in using IWB in teaching and learning. In this regard, Essig (2011) argues that teachers get motivated with the use of IWB because it promotes engagement and participation among the learners.

Some of the teachers experience challenges with the integration of IWB in teaching and learning. In case, it was reported in in this study that teachers were not properly trained and lack confidence to use the tool. These teachers resorted to use whiteboard. In some instances, some of the IWB froze while in use and teachers did not have an idea to trouble shoot the system. The other challenge that was encountered by the teacher was the slow access of IWB to open. This imparted negatively on the lesson because they only had 30 min. Some of the teachers could not operate some of the features like audio to enhance their lesson. Teachers revealed that the training was insufficient. Research shows that teacher need to receive sufficient training that is pedagogical, content and technological in order for the teacher to be able to integrate IWB in their teaching practice (Simelane-Mnisi & Mji, 2016). It is clear in this study that teachers encountered challenges such as IWB affects eyes, takes time, no electricity; lack of internet connection and security. Literature revealed that IWB promote teacher centered approach though it promoted the use of technology efficiently (Al-Faki & Khamis 2014). This was also observed in this study.

Conclusion

It may be concluded in this study that the use of IWB in teaching and learning had successes and challenges. The success that were identified were operating the IWB, using interactive textbook,
reuse the material, using hands to control the material, engaging the learners and participation, reduce workload, and gain confidence in the use of IWB. On the other hand, the challenges that were encountered in this study were not properly trained and lack confidence to use the tool, technical challenges such as freezing, and takes time to load, lack of trouble shoot IWB, health hazards, lack of internet connection and security.

**Recommendations**

It is recommended that continuous professional development and sufficient training be provided in order for the teachers to be able to integrate IWB effectively in their teaching practices. It is crucial that teachers are provided with technical support so that they do not focus on the technical challenges of the IWB but focus achieve the objective of the lesson. It is critical that sufficient interactive materials be available on the IWB and not only textbook.

**Reference**


IDENTITY CONSTRUCTION USING WHATS APP AS A MEANS OF LEARNING MATHEMATICS
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Abstract
WhatsApp have recently gained popularity as a learning platform that enhance mathematics through communication and interaction. This came when one of the more persistent and widespread problems in education at secondary education existed, to have mathematics being a favourite subject for learners. They believed that mathematics was hard, rigid and very hard to be communicated among them. A variety of studies has sought to understand mathematics phenomenon from learner’s viewpoint. This paper argues that mathematics can be communicated by learners while relaxing using informal learning by constructing their identities in social networks. Putnam’s social capital theory was used as a lens of the study Findings from the evidence of the study intrigued me to argue that learners who opted to engage in extensive informal communication using social network developed a sense of identity. This identity construction reverberated in enhancing motivation and learning of mathematics after hours. Three forms of identity construction was identified from data which laid solid argument for proposing model for using WhatsApp for identity construction in a similar resource constrained environment.

Key words: Identity construction, ties, WhatsApp, rural secondary schools, social capital theory

Introduction
WhatsApp is one of the pervasive and ubiquitous tool that is embedded as a daily routine in the lives of the teenagers at secondary school. Learners in this case study were not hindered from being at the rural area to access it. As a platform that could be integrated in the teaching and learning after school hours, it was observed as having potential of offering new possibilities among learners that of self-presentation, impression and identity formation as means of learning mathematics.

Literature review
Recent years have witnessed the rapid proliferation and widespread adoption of a new class of interpersonal communication which allows networking, collaboration and interaction using internet-based platforms. There has been a paucity of information regarding this in the rural secondary schools. Learners have decided to play an initiative role in using digital and networked technologies by satisfying their curiosity and share new findings (Dabbagh & Kitsantas, 2011) McLoughlin & Lee (2007) refer to this process as ‘learning on demand’. They use either mobile learning (Sharples & Pea,
2014), or a Personal Learning Environment (PLE) (Manathunga, Hernández-Leo, Caicedo, Ibarra, Martinez-Pabon & Ramirez-Gonzalez, 2015). These learning platforms have been applauded with a potential promising pedagogical approach enabling both integration of formal and informal learning using social networks (Dabbagh & Kitsantas, 2011). The similar trend has been adopted since there has been a growing evidence that usage of social networks are increasingly getting acknowledged for supporting informal learning and a vital element for learners education of all ages (Selwyn, Potter & Cranmer, 2009; Selwyn, 2007). Using WhatsApp accommodated dyadic interaction involved facial, vocal and gaze behaviours, partnership comprised of two firms. This allowed four interaction modes which were merging, teaming, mutual-partaking and sharing-dominated. It was only the two communications that played a fundamental role, where person to person transaction took place with assurance of provision of continuous feedback. The meaning exchanged between the sender and receiver is marked by high fidelity (meaning high degree of faithfulness to the original). To achieve fruitful communication and conversation, WhatsApp’s dialogue in a learning platform came to the forefront in an effort to construct identity among learners. The teacher cannot construct learner’s identities but they are responsible for their own educational growth. “Only through communication can human life hold meaning. The teacher’s thinking is authenticated only by the authenticity of the students’ thinking. The teacher cannot think for her students, nor can she impose her thought on them. Authentic thinking...[takes place] only in communication” (Freire, 2012).

Theoretical framework

It was of paramount importance to understand the role of WhatsApp as a learning platform and its ability of promoting the flow of communication, self-representation, and identity construction. Social capital theory enables this study to explore the amount of trust and reciprocity among individuals and community members (Putnam & Borko, 2000).

Methodology

Three mathematics focus groups from three schools were recruited to form WhatsApp groups by their mathematics teachers. I ended having 30 learner participants who were learning mathematics informally, after school using WhatsApp, voluntarily as a learning platform. Data was collected through focus group interviews, non-participating observation following them in their groups and documentary evidence, which was their class work during the once off visit in their classroom.

Research question

“How do learners learn mathematics through identity construction when using WhatsApp?”
The sense of identity formation facilitated interactions by enabling learners to engage in discrete, isolated and distant communication while acknowledging the social relations, flows and proximity. This facilitated the discourse of understanding mathematics which was lagging.

**Findings**

I observed the participants as a non-participant observer and I noted that: Participants of WhatsApp learning platform designers have the power to determine the types of content that they want to embed in their digital profiles and how this profile ought to reflect an offline identity. These findings were crafted by noting how information spreads across the network and influences the users. The snapshot was used to confirm the above finding:

![WhatsApp chat screen](image_url)

Learner’s understanding was crafted with the repetition, and introduction of new explanation. The whole group could easily absorb the clarification and the level of trust on this explanation was good.

Also, the interview from the focus group gave indication of how much trust is:

“I like Facebook more than other social networks, because one can have friends all over the world. I used to follow xxx (their teacher) in Facebook, I was so happy when I saw that xxx answered me (FGC3).

“I never thought that I will use these social networks......I studied EMS and I was told that they are good for marketing your business.......although I do not have a business now I am looking forward to have it one day...... I have used WhatsApp so far but I am looking forward to familiarize myself with all of them” (FGC5).
"WhatsApp is very easy and straightforward, and most of phones comes with it readily available connections. I like it because we share videos, important information, emails, announcements, files, voice notes and pictures easily" (FGC7).

Platform provided accurate and equal information about the network structure, allowing participants to employ information to networks strategically in ways that may influence the development of a network and relationship within the community.

In an attempt to define and explore how ‘identity’ was constructed I identified the three important components which saturate identity formation, which were sense of belonging to a group, a sense of achievement within the principles of the group impression management where group member could accommodate that particular identity formation. WhatsApp communication endorsed among group members element of trust, strong interaction and total reliance upon the new identity that has been constructed using platform. It was easy for the learners to use the already posted mathematical problems, revise using them, reflect on their understanding, and the shortage of books was no longer an issue. Resiliency sustained their goal. Above from the dyadic dialogue, I observed the new trilogy communication which can be displayed in the following diagram:

Figure 4: Trilogic interaction that enabled learners to construct their identities
Above trilogy of WhatsApp intervention in the construction of learner’s identity gave me the three spheres of the identity formation: their identity was cognitively constructed, they were always available for group members’ support and they could play the role of being a teacher too.

**Conclusion**

Evidence from the study enabled me to identify that learners who engage in WhatsApp communication as learning platform after school, established their stances in identity formation while learning mathematics in a very informal manner. Critical to this was how identity construction enabled them to understand themselves in particular their understanding of mathematics. Their meaning of mathematics was constructed through their negotiations, communications, and argument. The three spheres of their identity formation were noted.

**References**


SUSTAINING HANDS-ON PRACTICAL DEMONSTRATIONS IN CIVIL TECHNOLOGY THROUGH MULTI-MEDIA RESOURCES

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Abstract
This paper reports about the extent to which teachers use multimedia resources to demonstrate hands-on practical tasks of Civil Technology. A lesson of phase one Civil Technology PAT grade 12 for the year 2018 was observed to explore the practice. This paper argues that in this day and age, it is virtually impossible to ignore the use of multimedia resources, moreover videos when teaching. However, noting that some teachers in the technical education discipline undermine the impact multimedia has on young people and how it can be used to advance practical skill learning. Therefore, this study is concerned with how prepared are teachers to use videos, pictures and poster-charts in demonstrating hands-on practical tasks to learners? Bandura’s Social Learning Theory was used as a framework for this study. With the findings of this study, the researcher aims to advise Civil Technology teachers on benefits of using multimedia when teaching hands-on practical lessons to sharpen learners’ skills necessary for trade and industry work.

Introduction
Learning Civil Technology at the school level is not about discovering new or unknown ideas. Rather it is about capacitating learners with hands-on practical skills that are known and needed in engineering as well as artisans’ sectors [Department of basic education (DBE), 2011]. Therefore, a wide range of information is always acceptable to fulfil this Civil Technology aim. For instance, internet which has allow many to access and create their own media (Kutty & Thambu, 2017). The changes in education has witnessed information undergoing digitisation where the use of pictures and videos are becoming rapid contributors to the education system.

According to Puspita and Rohedi (2018) video usage is generally high to students on internet bandwidth. This implies that more young people are using videos to access information, moreover on YouTube (Hutchinson, 2017). Therefore, it can be appreciated to see videos, pictures and poster-charts contribute to the demonstration of hands-on practical activities in Civil Technology. Taking advantage of social practices of young people to skill them is what most countries currently need. However, what remains a concern is, how prepared are teachers to use videos, pictures and poster-charts in demonstrating hands-on practical tasks to learners? Which multimedia resources are available for enhancement of teaching and learning for Civil Technology? This article intends to explore these questions.
Literature review

It is virtually impossible to ignore that the need to use multimedia resources in teaching and learning is increasing, especially in technical subjects where many teachers have indicated a challenge in competency when demonstrating practical tasks (Rienties, Giesbers, Lygo-Baker, Ma & Rees, 2016; Solomon, 2016). Other researchers in the discipline, has suggested that the lack of infrastructure in workshops is a hindrance to the meticulous demonstrations of hands-on practical tasks (Habib & Nsibambi, 2014). On the other hand, some indicated that Civil Technology subject in schools is not offered enough time to do practical tasks as periods are shared equally with theory-based subjects (Maeko & Makgato, 2014). While these concerns are often raised, little is done to overcome them.

To date, teaching and learning has been primarily conducted on face-to-face interactions even when overcrowding of learners in workshops is reported (Hartman, Renguette & Seig, 2017). Practical tools and equipment in workshops are often reported to be lacking or not enough to cater the available number of learners. As a result, compromising on quality demonstrations of practical skills increases which renders teachers to produce practical unskilled-competent learners (Zhang, 2009). Thus, the use of audio-visual multimedia resources to bridge this gap of craft knowledge in Civil Technology is a demand to be attended to urgently (Alfar, 2009; Aloraini, 2012).

There has been an outcry to capacitate teachers with knowledge of using multimedia to teach lessons. DBE has responded to this outcry as it is currently forming part of its year 2030 goals. According to DBE’s goal 20 of the 27 schooling 2030 goals, there should be growth in learners’ access to a wide range of media, including computers to enhance their education. Therefore, video clips and posters should be used to supplement traditional teaching that does not cater for learners who are overcrowded in workshops. Seeing that (Wieling & Hofman, 2010) agrees that multimedia helps learners to improve performance, it is palpable to contend that multimedia can be used to improve hands-on skills of learners.

Based on the literature provided above, the following questions were asked:

RQ1: How prepared are teachers to use videos, pictures and poster-charts in demonstrating hands-on practical tasks to learners? (Observation instrument was used)

RQ2: Which multimedia resources are available for enhancement of teaching and learning for Civil Technology? (Interview instrument was used)

Methodology

This study used qualitative research approach. Purposive sampling was used to identify 63 learners and 5 teachers of Civil Technology. The researcher identified teachers who have expertise and
experience in Civil Technology field and who volunteered to take part in this study (Creswell, 2013). Data was analysed using a narrative enquiry approach which allowed the researcher to be descriptive in explaining phenomena as well as be explicit in dialogical discussions. Therefore, in this study, the interpretations of observation and interviews were reviewed by the participants as well as Civil Technology teachers in Sasol 3rd Annual Technical Teachers conference 2018 and they confirmed them as true reflection.

**Theoretical frameworks**

This study employed Bandura’s (1977) Social Learning Theory (SLT). SLT suggests that people learn from one another, via observation, imitation, and modelling. This study used SLT themes such as attention, retention, reproduction as well as motivation (Bandura 1997). Where; Attention posits that various factors increase or decrease the amount of attention paid. Ideally, attention happen where a teacher introduces new concepts to learners by using various strategies or sources to describe occurrences. This study explores which sources does the teacher use to describe how a practical task is executed.

Retention means remembering what you paid attention to. In this study, we explored how learners recall the knowledge gained from video-clips, pictures or chart-posters to begin with their practical task.

Reproduction means reproducing the image. Including physical capabilities, and self-observation of reproduction. In this study, we explore how learners imitate phenomena described to do their own task.

Motivation- having a good reason to imitate. Includes motives such as past (i.e. traditional behaviourism), promised (imagined incentives) and vicarious (seeing and recalling the reinforced model). In this study, learners affirm their skill competency and indicate self-independency where they can make artefacts to sell them or be competent enough to pass a trade test.

**The way forward**

This study will present results and discussions of what unfolded during data collection.

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CHALLENGES OF INTRODUCING GEOGRAPHICAL INFORMATION SYSTEMS AND REMOTE SENSING IN ZIMBABWE’S CURRICULUM FRAMEWORK FOR PRIMARY AND SECONDARY EDUCATION 2015-22

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Abstract
A qualitative and interpretative ethnographic research design informed by Grounded Theory was used to analyse the challenges of introducing Geographical Information Systems (GIS) and Remote Sensing in Zimbabwe’s Curriculum Framework for Primary and Secondary Education, 2015-2022. Four of the researchers were participant secondary school geography teachers in schools where GIS and Remote Sensing were introduced. One of the researchers participated in curriculum development workshops organized by the Ministry of Primary and Secondary Education on GIS and Remote Sensing in the new curriculum. Four schools were purposively selected in Harare, Mashonaland East, Mashonaland West and Midlands provinces to facilitate in-depth interviews, focus group discussions, class observations and document analysis of curriculum materials. Field data was coded and categorized and progressively narrowed through continuous sifting, sorting, reviewing and reflection so as to understand emergent patterns and recurring themes. The research established that Zimbabwe needs to expand the range of skills in information and communication technology offered in its school curriculum, if its citizens are to participate actively in today’s rapidly modernising and global society. The introduction of Geographical Information Systems (GIS) and Remote Sensing in the Curriculum Framework for Primary and Secondary Education, 2015-2022 is a notable response to this need. However, the innovation is fraught with challenges. These range from the shortage of resources such as GIS laboratories, computer hardware and software, in-service training, internet connectivity, and relevant textbooks in some schools especially rural secondary schools, to lack of administrative support and teachers who are knowledgeable in Geographical Information Systems and Remote Sensing. The paper recommends more in-service training, GIS and Remote Sensing curriculum materials, internet connectivity, GIS infrastructure and software, and making GIS and Remote Sensing optional rather than compulsory so as not to disadvantage poorly resourced schools. The curriculum innovation should certainly not be abandoned but implemented with care and caution. For a start, the zeal exhibited by learners to embrace GIS in and Remote Sensing when the requisite infrastructure and teaching personnel were available was quite encouraging.

Keywords: Geographical information systems, remote sensing, interpretive ethnographic design, curriculum development
AN EXPLORATION OF THE RELATIONSHIP BETWEEN ENGINEERING GRAPHICS AND DESIGN TEACHERS’ UNDERSTANDING OF ASSEMBLY DRAWING AND THEIR TEACHING OF ASSEMBLY DRAWING
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Abstract:
This study explored the relationship between teachers’ content knowledge and their pedagogical skills, and reports on that relationship in the teaching of Assembly Drawing (AD) in a South African context. Given that Engineering Graphics Design (EGD) learners perform poorly in the AD section of the matriculation examination, we need to understand the extent to which this results from the quality of teaching. A case study approach was used to collect qualitative data from 25 purposively selected EGD teachers in the UThukela district of KwaZulu-Natal (KZN). Data was collected via an open-ended questionnaire, focus group interviews, lesson plans, observations, and post observation interviews. Our findings elucidate the relational interplay between teachers’ understanding of AD and their teaching of AD. The majority of teachers failed to develop visual, spatial skills in learners. Our findings have implications for continuous teacher professional development.

Introduction
Learners write two papers (paper one and paper two) in Engineering Graphics Design (EGD) for the National Senior Certificate (NSC) examination. In paper two, the section of mechanical assembly, which is weighted the highest, includes Assembly Drawing (AD). Learners perform poorly in AD. The National Senior Certificate EGD examiners and moderators report (DBE, 2012-2014) reflects that EGD learners encounter difficulties in attempting to answer questions pertaining to AD and highlights areas of learners’ weakness and misconceptions related to AD (DBE, 2012, p.4). These examiners’ and moderators’ report are sent to all schools for the attention of the principal and EGD teacher/s, so the identified areas of weakness and learner can be addressed but the misconceptions and identified areas of weakness pertaining to AD persist. Sotsaka (2015) and Tholo, Monobe and Lumadi, (2011) assert the successful implementation of any curriculum is dependent on teachers having a solidly established personal construct (PCK) and their context to engage effectively with the engineering sciences, design process and the mathematical and analytical reasoning associated with AD. This article explores the relationship between teachers’ understanding of AD and their teaching of AD. The argument put forth is that when EGD teachers do not understand or have a shallow understanding of AD, they are not likely to teach AD in ways that will help learners understand it.

Literature Review
Shulman (1987) envisages PCK as the knowledge that teachers use in transforming content knowledge into forms that make or promote learning possibilities. It includes knowledge about how learners learn, and the ability to predict common misconceptions or preconceptions. Simply put, this means that PCK is a fusion of both content knowledge (CK, knowing what to teach) and pedagogical knowledge (PK, how to teach). A teachers’ CK can be highly specialised (SCK). According to Ball, Thames and Phelps (2008), specialised content knowledge (SCK) refers to the information that the teacher has that is specifically related to the subject being taught and it includes the teacher’s ability to successfully organise this content into an appropriate teaching sequence. SCK refers to the knowledge and skills that all EGD teachers must construct and have to be able to teach EGD effectively in their classrooms.

**Theoretical framework**

In order to explore the relationship between teachers’ understanding and teaching of AD, our conceptual framework is an amalgam of Bloom’s revised taxonomy and certain components of Shulman’s (1986) PCK model. The PCK components used were SCK, knowledge of the curriculum, knowledge of instructional strategies and knowledge of learners’ understanding of AD. Teachers’ understanding of AD is a part of their SCK. As a way to represent teachers’ understanding of AD (their SCK) and to ascertain the level of understanding of AD used to facilitate learning, we draw on the cognitive dimension of the revised Bloom’s taxonomy (Anderson & Krathwohl, 2001). The cognitive level of teachers’ understanding of AD can be established by juxtaposing their understanding alongside Bloom’s levels of cognitive dimension with their accompanying cognitive processes.

A teacher’s teaching of AD is linked to knowledge of the EGD curriculum (knowledge of goals of EGD, curricula material, links between the purpose of teaching AD and teaching practice); instructional strategies (understanding and use of teaching strategies for AD, knowledge of specific task-based instructions) and knowledge of learners’ understanding of AD (misconceptions / preconceptions that will talk back to instructional strategies deployed). Resonance/alignment amongst the above-mentioned three components of PCK, together with the teacher’s SCK, is of pedagogical significance as it enables teachers to decide on effective instructional strategies for planning of lessons and assessments. To be able to illuminate the link between teachers’ understanding of AD (SCK) and their teaching of AD in this study, we juxtaposed teachers’ understanding (SCK) with the three components of our conceptual framework. This will illustrate how teachers’ understanding of AD impacts their lesson planning and their eventual teaching of AD.

**Methodology**

In this qualitative case study data was generated in four stages via the use of questionnaires, focus group interviews, lesson plans, classroom observations, and post observation interviews respectively. Permission to conduct this study was obtained from the relevant gatekeepers, the university’s ethics committee, KwaZulu-Natal (KZN) provincial department of basic education,
principals and EGD teachers. All respondents were assured of anonymity and confidentiality. 25 teachers of EGD were purposively selected to participate in the study and all respondents agreed to participate in the study.

Data generated was inductively analysed. Content analysis was used for the questionnaires, lesson plans, transcripts from the lesson observations and interviews. The data was read several times before similar /meaningful words and phrases were noted and then grouped into categories. The verbs teachers used in their understanding of AD were used to establish their level of understanding, as per the revised Bloom’s taxonomy. Once teachers’ level of understanding of AD was established, the levels were juxtaposed with objectives from their lessons and their teaching/assessment activities for AD, as stated in the lesson plans. Lesson objectives of these plans were identified in two ways: as they were stated explicitly in the plans by the teachers themselves, or as they were inferred by us from the teaching/ assessment activities described in the plans. The teaching/assessment activities were examined as they illuminated insights about teacher knowledge of the curriculum and knowledge of learners’ understanding of AD. Juxtaposing the teachers’ understanding (SCK) against the three elements of our conceptual framework enabled us to make visible the interplay between teachers’ understanding and teaching of AD. As part of the analysis process, data from stages 1-4 was (re)assembled and juxtaposed to trace the interplay between EGD teachers’ understanding and teaching of AD.

Findings and conclusion

Our findings reveal that teachers of EGD have 3 key understandings of EGD, each understanding is associated with a corresponding teaching strategy as reflected in table 1 below:

<table>
<thead>
<tr>
<th>Conceptual understanding of AD</th>
<th>Corresponding strategy teaching</th>
<th>Number teachers of EGD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Putting together components</td>
<td>Chalk and Talk</td>
<td>20</td>
</tr>
<tr>
<td>Putting mechanical parts, to facilitate an understanding of how they all function</td>
<td>Lecture/discussion/demonstration</td>
<td>3</td>
</tr>
<tr>
<td>Involves visual reasoning, thinking of graphical images of mechanical components, manipulating them then putting it in a diagram according specifications</td>
<td>Project based hands on learning</td>
<td>2</td>
</tr>
</tbody>
</table>

Our findings exemplify the intertwined relationship between EGD teachers’ understanding and teaching of AD. Our findings illuminate that deep understanding of AD affects the teaching of AD, including the formulation and design of assessment and teaching strategies used to teach AD. Our findings support our argument that a teacher’s SCK affects the quality of his/her teaching. Our findings resonate with those of Alonzo (2002) who demonstrates that in mathematics, teachers who understood multiple representations of mathematics concepts were able to use those representations in their teaching practice to promote learner engagement. This means that teachers
with deeper SCK were more likely than those with weaker knowledge to engage learners in meaningful learning through their classroom activities and teaching strategies (Alonzo 2002). Additionally, our findings illustrate the impact that the school ecology (contextual factors) and the professional activities that teachers engage in, have on their PCK. The findings of this study have implications for: EGD subject advisors, the continuous professional development of EGD teachers, the current models used to workshop EGD teachers during curriculum reform, and the training of pre-service EGD teachers.

References


FINDING AND DEFINING WOMEN CHAMPIONS IN A COMMUNITY BASED RURAL ADULT ICT EDUCATION INTERVENTION IN LIMPOPO

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Abstract
This paper examines a rural community education programme for vulnerable young mothers in Limpopo Province — identified as a priority group for human development and the eradication of poverty. The project comprised a combined course in ICT and BAE nutrition skills, negotiated with the young women in advance, to meet their needs.

Our objectives involved: assessing effectiveness of CBPAR methodology in implementation of the programme; evaluating the CoP set up to design and implement the course, and exploring ways to stimulate community interaction and promote continuous improvement.

Research questions:
   a) How do we use CBPAR, to provide young mothers with effective ICT and nutrition training in a rural area?
   b) How do we implement community-based training courses and ensure they are sustainable?
   c) What structures and systems are needed to set up effective CBPAR studies to ensure they are relevant and beneficial?

The methodology involved a 3 stage, 5 phase, CBPAR process to structure the study. A CoP was established to support the intervention and initiate future local support. Community participation was promoted to ensure continuous improvement.

Results demonstrated that CBPAR aided implementation, empowered individuals and strengthened the roles of participants. Participants showed motivation to learn and willingness to volunteer to enhance vocational and life skills. Sustaining the course required motivated champions; prudent management and careful application of technology.

In conclusion, CBPAR proved effective for establishing and monitoring adult ICT education interventions. It is recommended that future studies address gender-specific adult education. National investment is essential to empower unemployed young mothers to become leaders in community development. Community based adult education is beneficial for vulnerable groups, in rural areas, by empowering champions to sustain future courses.

Introduction
A recent study, in a remote rural village in Eastern Limpopo, researched implementation of an ICT and BAE Nutrition course for young mothers (YMs) using a community based participatory action research (CBPAR) approach. It attracted 20 unemployed YMs, in the age range 18-30. YMs are a vulnerable social group in South Africa’s rural areas (Chopra, 2003). Studies reveal many are poor, unemployed and lacking in basic education. They form a significant number of the 60% school-going population that fails to complete secondary education and matriculate at grade 12 (Spaull, 2015). Creating adult education (AE) opportunities is necessary to develop rural communities and prevent migration to cities. Practical ICT training enables YMs to develop vocational skills to work from home or develop employment locally where skills are scarce.

The key research question:

What structures and systems need to be in place to create an effective CBPAR study which can render an intervention relevant and purposeful for the group it is designed to benefit?

To understand these structures and systems, within the context of a practical training intervention for YMs delivering ICT skills and basic adult education (BAE) theory, the main question was divided into sub-questions:

RQ1: How to establish a community of practice (Lave, 1991) to design and implement an ICT training course which includes BAE nutrition education?

RQ2: How do we implement community-based ICT and nutrition training courses for YMs in rural resource limited settings such that they are sustainable?

RQ3: How do we stimulate further constructive interaction as part of establishing a process of continuous improvement, through direct engagement (Pain et al., 2012)?

A community of practice (CoP) was established to develop an adult education centre (MECP) in Mulamula. It was to be the location for the study but power supply issues meant that the location was relocated to a local school. The decision to focus on young unemployed single mothers was agreed in traditional council meetings discussing vulnerable groups in the community requiring support and training. YMs were recruited using a community workshop and by word of mouth. Progress was monitored and analysed using qualitative techniques.

Study data was gathered over 6 months using volunteer trainer/facilitators using manual and computerised tools including: application forms, surveys, interviews, email, Skype and WhatsApp dialogues. Data was analysed thematically using QSR NVivo v10 software and MSOffice Excel tools. Framework analysis involved 5 stages of refinement to familiarise, code, frame, analyse, and chart content thematically from transcripts.
The study revealed issues relating to: establishment of training programmes; motivating participants; maintaining communications; monitoring and evaluating progress and how community-based AE empowers individuals in rural communities. It demonstrated that practical skills training motivated marginalised YMs who made sacrifices to attend. It revealed more motivated individuals willing to promote, improve and support the intervention. Group evolution was significant: foregrounding YM’s leadership and entrepreneurship qualities. YMs emerging with these qualities were identified as ‘champions’ for future interventions.

The combined ICT training and BAE Nutrition course provided a relevant theoretical context to use for developing portfolios of ICT work. The contextualised approach was appreciated. The group were taught in a informal but structured manner which catalysed self-development and strengthened social networks.

Categories of ‘champions’ emerged in terms of: commitment at different periods and influence on the 5 CBPAR phases of the intervention. Some emerged as ‘leader champions’ demonstrating willingness to help and inspire others to higher learning and improving quality through constructive feedback.

Results affirmed assumptions relating to communities of practice (Lave, 1991; Wenger, 1998, 2011) and practical appreciation of CBPAR (Cooperrider, Whitney, & Stavros, 2008; Horowitz, Robinson, & Seifer, 2009). They revealed both resilient and transient forms of ‘champion’ influencing events periodically and inspiring others to participate fully as ‘future champions’.

Localised AE was appreciated as it unified YMs isolated by social circumstances. By meeting and collaborating, YMs overcame fears and prejudices. The ‘champion’ YMs emerged early on and remained a constant influence inspiring more isolated YMs in the community to come forward.

**Literature review**

Literature reviewed covered participatory (Cornwall & Jewkes, 1995; Pain, Whitman & Middledge, 2012) and inclusive approaches to research (Horowitz, Robinson, & Seifer, 2009). Recurring themes from rural interventions emerged relating to: definitions of rurality (Hart, Larson, & Lishner, 2005); empowerment of women (Batiwala, 2010); marginalised undernourished communities (Chopra, 2003), feminist leadership (Bunch, Carroll, White, Caldicott, & Leadership, 2002) and women’s emancipation from poverty (Joachim, 2013). ICT training for women in rural communities emerged as a specific research gap.

Community based participatory action research (CBPAR) was identified as a suitable approach through studies of rural interventions (Maiter, Simich, Jacobson, & Wise, 2008; Mckay, 2011). CBPAR has been employed in capacity building and training in healthcare research in rural communities and is recognised as an effective approach for inclusive action research (Balazs & Morello-Frosch, 2013).
In order to establish an authentic ICT training programme in a remote rural location it was identified that the establishment of a community of practice (CoP) (Lave, 1991; Wenger, 1998) was necessary to set up systems and establish networks of cooperation.

During the study of CBPAR, appreciative inquiry (AI) methods (Cooperrider et al., 2008; Kevany & MacMichael, 2014; Reason & Bradbury, 2001) were identified to assist the interpretation of data and subsequent analysis. As the study was drawing data from a wide range of diverse sources, framework analysis was identified (Ritchie, 1994) as an effective approach to structure the analysis of data.

**Conceptual and Theoretical Framework**

The conceptual framework drew on a 5 step CBPAR action research approach (Balazs, & Morello-Frosch, 2013). This included phases of planning, action, observation and reflection common in AR models (Lewin, 1958; Stringer, 1999; McNiff & Whitehead, 2005). The study was situated in critical theories (Geuss, 1981; Kemmis, 2006) integrating elements of social science and supporting emancipation of marginalised individuals within historical events. Habernas’s view of critical social theory as a study of communication (Geuss, 1981) relates to the web of communication modes employed in this study which seeks participants’ growth and relief from poverty.

As there were a number of levels of action, involving different stakeholders, a phased approach, below, was used to organise and prioritise activities:

**Stages of the CBPAR process**

A five-phase model structured the community based participative action research (CBPAR) process:

- **Phase 1. Getting stakeholders to agree a long-term vision for the process.**
- **Phase 2. Creating infrastructure for the process that fostered participation and engagement.**
- **Phase 3. Developing community links that sustained commitment from all members.**
- **Phase 4. Orientating systems to enable long term function of the process.**
- **Phase 5. Pursuing goals which were of value to all stakeholders – following outcome-based advocacy.**

To manage implementation, phases were aligned to stages in the chronological order of events. This enabled identification and extraction of relevant data from establishment of the CoP through to the conclusion of the course. Shown in table 1 below.

*Table 1. Relating RQs to CBPAR phases and objectives*
<table>
<thead>
<tr>
<th>RQs</th>
<th>Phases of CBPAR</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>RQ1: How to establish a community of practice (Leve, 1994) to design and implement an ICT training course which includes BAE nutrition education?</td>
<td>1. Getting stakeholders to agree a long-term vision for the process.</td>
<td>• Building a community of practice by establishing the needs of YMs through direct engagement with the community and by agreeing a roadmap for the implementation with stakeholders.</td>
</tr>
<tr>
<td></td>
<td>2. Creating infrastructure for the process that fosters participation and engagement.</td>
<td>• Designing a combined ICT and basics nutrition course using a participatory process which fitted the needs and aspirations of the participants in the village environment.</td>
</tr>
<tr>
<td></td>
<td>3. Developing community links that sustain commitment from all members.</td>
<td>• Recruiting YMs using different tools; Enlisting the help of local community volunteers. • Developing a network of support between the trainer, facilitator and Mahlefunye Primary school to establish the course practically and trial the YMs’ course in advance.</td>
</tr>
<tr>
<td>RQ2: How do we implement community-based ICT and nutrition training courses for young mothers in rural resource limited settings such that they are sustainable?</td>
<td>4. Orientating systems to enable long term function of the process.</td>
<td>• Inviting YMs to participate using a community workshop. • Implementation with volunteer trainers over a 6 week period, monitoring participants’ progress and gathering data using tools to monitor effectiveness and identify improvements.</td>
</tr>
<tr>
<td>RQ3: How do we stimulate further constructive interaction as part of establishing a process of continuous improvement, through direct engagement (Pain et al., 2012)?</td>
<td>5. Pursuing goals which are of value to all stakeholders – following outcome-based advocacy.</td>
<td>• Evaluating training with participants to reflect on the process and its effect on them. • Construct practical goals to share with the community – in particular the emerging leaders from the YMs’ group - to help sustain training in future.</td>
</tr>
</tbody>
</table>

**Methodology**

Methodology was developed using established 5 phase CBPAR models (Maiter, Simich, Jacobson, & Wise, 2008; McKay, 2011). Choice of CBPAR was influenced by its use in practical interventions in resource limited settings. In addition, appreciative inquiry (AI) methods (Cooperrider et al., 2008; Kevany & MacMichael, 2014) were emphasised during interpretation of data and subsequent analysis. A cyclical reflective model (Pain, Whitman, & Milledge, 2012) helped address issues of community reciprocity and foreground continuous improvement. This model guided validation of the research instruments (see figure 1).

**5.1 Methodology Summary**

To address the RQs, the ICT basics course developed included contextualised nutrition examples. The study was located in Mulamula in the Vhembe district of Limpopo. Various locations in the village were used: traditional council office, MECP hall and Mahlefunye Primary school. The main location for the YMs’ course was the school’s computer room.

The course initially followed a recognised international computer training structure. Contextual BAE nutritional content was included in collaboration with trainer and facilitator. The course was proposed and refined with the participants: trainers, facilitators, YMs, school head and village
stakeholders after dialogue to establish a CoP. It was trialled with grade 12 learners and educators in after-school sessions.

The final course ran over 6 weeks with 20 YMs. To stimulate participation in the process, YMs were: recruited at a voluntary workshop; encouraged to recruit peers and contribute to course design; interviewed during and after the course. The trainer/facilitators and school Head were involved continuously in course refinement providing feedback via online dialogues. Ultimately, all participants were given the opportunity to provide critical feedback through interviews and feedback forms.

5.2 The Trainers
Classes were taught by a graduate of Polokwane IT training school and a German degree-qualified IT specialist volunteer. Both grew within the experience by appreciating the needs of YMs in rural communities and reflecting on their own strengths and weaknesses. Through online reports, they shared experience readily as ‘digital natives’ comfortable using technology for communications (Prensky, 2001). Their regular feedback essential in understanding YMs’ participation while their cultural perspectives assisted in triangulating data.

5.3 Collection of data
Data was collected over 6 months. (see: Table 3). The focus of data collection was to track participation of the YMs through their feedback and the observations of trainers and course facilitators. Pre-implementation data, provided insights into how the research was located in the village and stakeholders’ involvement in the CoP.
Different tools were used to collect biometric and qualitative data from YMs and other key participants. Minutes of meetings, formal letters and MECP newsletters provided validating data to clarify the timeline of events from CoP inception to the course conclusion. (See: Table 4):

These helped triangulate information relating to key events. WhatsApp ‘free’ cell phone messaging service elicited rapid feedback from participants and was vital for remote management of the study.

5.5 Study sample
Twenty YMs attended the final ICT and BAE Nutrition course. The eligibility criteria used in the study (YM in the age range 18-25 with at least one child under the age of 5) meant that the main focus of interviews was 6 YMs. In addition to the course attendees, the trainer, facilitator, MECP founder, school Head, and tribal council also contributed to the study providing interview responses, feedback on training and additional data.

5.6 Analysis of data
Analysing data gathered over a period of six months, it was necessary to retain focus on research questions keeping rigorous chronological records and transcripts.

5.6.1 Quantitative analysis
Limited quantitative biometric data was gathered using application forms, training registers and follow-up interviews. This was used to establish how YMs fitted the eligibility criteria and to clarify marital and employment status.

5.6.2 Qualitative analysis
A grounded approach was used to analyse qualitative data in the form of interview transcripts, cell message strings and evaluation forms. Line by line reading, tabulating and initial coding familiarized the researcher with the content. To structure the data thematically, framework analysis was done with co-author supervisors (Ritchie, 1994). Data was indexed into categories using MS Excel spreadsheets and thematic coding applied to rate data by relevance to the RQs. Themes were refined in NVivo to extract common themes enabling key findings to be isolated and given contextual value.

Word frequency tools presented and triangulated dialogues from different sources and threads from participants. Data from specific events reflected different participants’ viewpoints to validate of results and draw conclusions. For example: observation feedback sought from the trainer, IT facilitator and Head of school, alongside YMs interviews, heightened understanding of lessons.

Charting and mapping articulated results alongside dialogue summaries discussed with participants in the CBPAR evaluative process.

**Preliminary Findings**

**2.1. Quantitative data**
Application forms provided insights regarding status and education of YMs. Additional biometric data was collected during: follow-ups with trainer/ICT facilitator; penultimate lessons and evaluation interviews. 90% of the 20 YMs declared themselves as unemployed. Three completed Matric and all had little or no practical computer experience. 50% failed to complete forms accurately meaning biometric data required verification during interviews.

60% admitted they were unemployed. 75% of the YMs, with children under 5 years old, responded that they were single - an alarming result. An additional concern was the unmarried ‘older’ YMs, out of school for more than 10 years, who were still unemployed.

45% stated willingness to volunteer at MECP to subsidise attendance and develop future ICT courses.

**2.2 Qualitative data**
The study reinforced the need for AE opportunities for YMs in rural communities. Early establishment of the CoP required interrelated meetings and agreements. Key planning decisions were made during a participative workshop where potential trainers, YMs, and community representatives discussed course content, community value and practicalities of classes. It created an adult forum with YMs treated equally in decision making processes. YMs contributed to organising of appropriate training days and times.
Implementation required flexible planning to engage YMs, trainer, facilitator and host school. Inclusion of contextualised nutritional examples was appreciated by the YMs. The few experienced users appreciated that contextualised learning of ICT skills was different to traditional methods. The ‘champions’ recognised applications to other life skills: child care, sexual health and accounting. The course was well received. Attendance grew progressively as word was spread locally using YMs’ informal networks which worked more efficiently than planned methods using traditional council structures. YMs emerging as ‘champions’ promoted activities within the class by helping weaker, less experienced, peers.

Transformation from English to a combination of XiTsonga and technical English was a significant improvement for teaching YMs with limited comprehension ability. After initial local trials, trainers changed roles. The German volunteer became technician and mentor to the locally trained graduate who used combined XiTsonga and English to teach. This signified an evolving participative process to improve pedagogy for the YMs. Team teaching empowered some and exposed others’ shortcomings and limitations. The YMs’ leaders articulated the group’s needs to the trainers adopting the role of peer tutors. ‘Champions’ gradually recognised personal potential to become future ICT facilitators.

**Significance of Findings**

“Women have led a lot but their leadership is not recognised”

(Bunch, Carroll, White, Caldicott, & Leadership, 2002)

Young mothers are unique individuals driven by many factors. Training attendance reflected personal motives: career progression; desire to socialise; sharing experience in a neutral setting and relieving boredom as single mothers. Mature ‘champions’ encouraged others to attend after assessing initial sessions themselves. Recruiting other YMs, they showed leadership and community initiative using peer support networks.

Development of community was a strong motivation. Individuals wished to improve their lives but stressed village improvement was vital. ‘Champions’ had clearer motives for participating but demonstrated empathy to support weaker students.

YMs valued ICT skills for employment and further study through access to online resources and recognised the need to mould ICT skills to vocations. Emergent ‘champions’, identified specialised software to pursue specific accounting or retail careers. Others wished to use the internet to access tertiary courses or study childcare and nutrition.

MECP was founded by a local woman promoting it as ‘democratic, legitimate and accountable’ (Batliwala, 2010, p. 18). YMs were keen to stake a claim in developing it. Contributions made to sustaining future training at MECP indicated philanthropic motives: desire to participate fully;
community development; and ‘claiming leadership’ in a location where unacknowledged labour is delivered by women. (Joachim, 2013)

Conclusions

Following a CBPAR approach in the implementation enabled observation of daily life in a rural village and revealed ways to establish training courses inclusively for YMs using limited resources. The CoP, enabled training to be responsive to YMs’ needs. They emerged as a complex group bringing different experiences, motivations and attitudes. The course created a forum where women were comfortable working together. ICT training imparted valuable vocational skills. Using nutrition as a context, the YMs completed tasks and practiced ICT skills. Discussions of nutritional content helped expose knowledge YMs lacked. The adult setting gave women a voice to raise issues and share aspirations.

‘Champions’ displaying leadership traits: promoted activities; supported others; mediated for the group and volunteered for the benefit of the community. These ‘champions’ showed willingness to learn skills to sustain an AE venue.

Using AE classes to study YMs is a valuable research approach. Learning using appropriate contexts, in a neutral setting, creates a productive atmosphere for self-development. Locally-based CBPAR studies, aid deeper understanding and become a catalyst for improving lives.

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Abstract

We live today in the knowledge society, based on the use of Information Technology in an atmosphere of network communication. The Information and Communication Technologies and their artifacts are present in all fields of activity. The problem is what to do with them. In the field of Education, many challenges are imposed on both teachers and students, both for enthusiasts of informatics for education and for the most critical septics of computerized education. This article is limited to the thematic axis of teacher training. In it, a questionnaire (online form) combined with the WhatsApp and Facebook communication tools was used to evaluate the electoral manifesto of a candidate for the direction of a faculty and to seek subsidies that could enrich the candidate’s governance program or the candidate who wins this election race that involved four candidates. The data produced in this tool were analyzed statistically and interpreted from the point of view of the production of meaning and the ethical act from the perspective of Mikhail Bakhtin. This study represents a guiding reference in the search of the potential of Information and Communication Technologies for Education, Teacher Training and participatory and democratic management.

Keywords: Unpredictability and learning, Collaboration, Technologies in education.
PROMOTING THE USE OF INQUIRY METHODS IN LIFE SCIENCE CLASSROOMS THROUGH OSHIKUNDU

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Abstract

The poor performance of Namibian secondary school learners in understanding certain science concepts such as enzymes as attributed in part to lack of scientific investigations being conducted in some schools. Oftentimes, some teachers blame lack of resources. It is against that background that this study uses a locally found resource to mediate the concept enzyme using an inquiry approach. It was informed by an interpretive paradigm. Within this paradigm, a qualitative case study was adopted. The study was conducted in two schools and two Life Science teachers participated. Questionnaires, semi-structured interviews and workshop discussions were used to generate data. A thematic approach to data analysis was adopted. Findings from the study revealed that the teachers seemed to have an understanding inquiry method but were not aware of using easily accessible resources to conduct these. The study thus recommends the teachers need to be empowered on how to use easily accessible resources in their classrooms.

Key words: Life Science, scientific inquiry, indigenous knowledge, socio-cultural theory, TSPCK

Background and Purpose of Study

The use of inquiry-based approach is strongly advocated for the teaching and learning of science (Dixon, 2015; Lamm 2017; Wells, 2011). This approach affords learners an opportunity to connect their learning to previous experiences. However, some teachers raise concerns in using this approach, notably referring to time constraints (Harmon, 2011). In addition, some complain about the availability of resources (Amir, Chong, & Siew, 2015). For instance, some studies revealed that in Namibian science classrooms teacher-centred approach still prevails and this is evidenced by the lack of practical investigations observed (Abah, Muyoyeta, & Denuga, 2017; Asheela, 2017; Nikodemus, 2017). In cases where teachers used practical investigations in their classrooms, it was observed that the practical activities did not promote inquiry skills (Kapenda, Kandjeo-Marenga, Kasanda, & Lubben, 2002). It is against this background that we conducted a study which sought to promote the use of inquiry methods using easily accessible resources. It was guided by the following research questions:

• What are grade 8 Life Science teachers’ experiences, perspectives and pedagogical insights on the use of inquiry methods?
• How can grade 8 Life Science teachers be supported in developing model lessons on enzymes using inquiry method?

**Literature and Theoretical Framework**

Inquiry is described as a cluster of learning and teaching approaches in which the learners’ inquiry or research drives the learning experience (Easterly, & Myers, 2011; Naude & Meier, 2016; Settlage, & Southerland, 2012). Inquiry in this study was promoted the Predict-Explain- Explore-Observe-Explain (PEEOE) (Maselwa & Ngcoza, 2003). The PEEOE approach entails allowing learners to predictions and explanations thereof before they do the investigation. Thereafter, they have to explore, observe and then write explanations of their observations. To achieve this, we used a cultural practice of making 21Oshikundu (Asheela, 2017; Nicodemus, 2017) to mediate learning of the concept enzyme (Dewar & Taylor, 2000) and to promote social interactions.

Vygotsky’s (1978) socio-cultural theory thus informed this study. Socio-cultural theory acknowledges that social interactions contribute to one’s cognitive development using cultural tools (Vygotsky, 1978). Additionally, drawing on Shulman’s (1987) seminal work, Mavhunga and Rollnick’s (2013) five topic specific pedagogical content knowledge (TSPCK) components, namely, learners’ prior knowledge, what is difficult to understand, curricular saliency, representations and conceptual teaching strategies were used as analytical tools.

**Research Design and Methods**

This study is underpinned by an interpretive paradigm (Cohen, Manion & Morrison, 2018; Creswell, 2014). Within this paradigm, a qualitative case study approach was adopted. The case study provided some insights on how people interpret their experiences, how they construct their worlds and what meaning they attach to their experiences (Eisner, 2017; Merriam & Tisdell, 2016). Data were generated using questionnaires, semi-structured interviews and workshop discussions. Data were analyzed by means of an inductive approach (Creswell, 2014).

**Sample**

A purposive sampling was used to choose both the participants and the school where the study was conducted. The two schools chosen are under-resourced which maximised the opportunity to demonstrate how locally found knowledge can be used to alleviate resource constraints.

21 Oshikundu is a non-alcoholic traditional beverage which is a traditional cereal based beverage which is made from fermenting three flours; malted sorghum (Ogundo), Uushutu, Mahangu. It is a staple drink for many Oshiwambo speakers in Namibia and it is a reach source of carbohydrates, proteins, vitamins and minerals. It also provides the body with water ideally for prevention of dehydration.
Pertaining to the four teachers, qualities such as being Life Science grade 8 teachers, experience with the Life Science content of the new curriculum were considered.

Findings and Discussions

The findings of this study revealed that the teachers involved in this study seemed to have experience in inquiry methods during their schooling years. They also acknowledged that inquiry is an important pedagogical approach (Asheela, 2017; Lamm, 2017). However, highlighted lack of resources as a constraint in developing inquiry skills in their lessons. These teachers were amazed to see that Oshikundu could be used to promote scientific inquiry as well as enhance conceptual development on enzymes and its associated concepts.

Conclusions and Recommendation

It seems the teachers involved in this study had an idea of inquiry methods. However due to limited knowledge on the use of locally found resources and how they are aligned to the school curriculum, teachers tend to find availability of resources a challenge (Asheela, 2017). That is why an intervention in a form of workshop could potentially engage teachers on how to identify and make use of local resources to promote both inquiry and understanding of content in their classrooms.

References


