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FOREWORD

Research in Science Mathematics and Technology (SMT) education is a complex process that is influenced by reciprocal interaction with learners, educators, parents and other stakeholders. One aspect that brings us together as SAARMSTE family is the belief that we are able to provide explanations to some of the challenges we encounter within this complexity. As a way to respond to this complexity, most countries are repositioning themselves within the context of global trends and campaigns such as Millennium Development Goals (MDG) and Education For All (EFA). They are reflecting on their education systems. For instance in South Africa (RSA) there has been a launch of Action Plan to 2014 – Towards the Realization of Schooling 2025. One aspect that has become more evident is how mathematics and science features in the goals of the Action plan as well as in the MDG and EFA. MSTE is acknowledged as playing a pivotal role as a link and solution to some of the 21st century challenges hence a bridge to the future.

The proceedings consists of Mathematics, Science, Chemistry, Physics, ECD and Technology papers. The papers in various strands reflect on some aspects that may need to be taken into consideration in order to address the challenges through creation of sustainable empowering learning environment as well as being sensitive to issues related to social justice within the context of SMT education.

The success of a conference depends on collective efforts by various people and stakeholders. Sincere gratitude is extended to the plenary speakers, reviewers for their willingness to assist even at times when we thought the “ship was sinking”. Their willingness to go an extra mile is heartily noted. May the spirit be extended to future conferences. We owe a debt of gratitude to Regional SAARMSTE EXCO for their consistent support and guidance from start to the end. To the Local Organising Committee (LOC) who were the “foot soldiers” that had to engage with issues at grass root level attending numerous meetings as we were getting everything into shape. We are particularly indebted to Susan van Rooyen and her team for their expertise and for taking care of the non – academic but core aspects of the conference.

Andrew Mutsvangwa, Noma Mokakale and Evelyne Ribane we wish to express our sincere thanks for your direct active role in assisting with the compilation of the proceedings and prompt response to queries on daily basis. Lastly but most important our thanks are also due to Prof Dan Kgwadi, the Campus Management, Dr D Gericke – Executive Dean: Faculty of Education and Prof Maselesele – Executive Dean:FAST, for making it possible for the conference to finally materialize. Ditebogo (gratitudes)) are also extended to various sponsors for their generous support.

We feel very privileged to have been involved in the proceedings and to have read a number of submissions because the contributions by various authors bring such diversity and alternative lenses of looking at challenges within SMT education. Although SAARMSTE is a regional body it is increasingly attracting more international participants and SAARMSTE - North West chapter regards itself as honoured to be granted an opportunity to host this important conference.
RE LEOBA GO MENAGANE

L.T. Mamiala

Chairperson: LOC
MESSAGE FROM THE PRESIDENT

It is a great pleasure to welcome you all to the 19th annual SAARMSTE Conference held at the North-West University in Mafikeng. At the outset I wish to thank the members of the LOC and many others who have given so generously of their time to organise this event. The SAARMSTE conference is a pivotal event in the annual calendar of SAARMSTE. It provides an opportunity for our researchers to come together and share our work. It also provides an opportunity for us to participate in and as a community of practice. It is important that our work is disseminated, critiqued and engaged with. Our theme this year is Mathematics, Science and Technology Education: A bridge to the future. We are all too aware that the future of our planet hangs in the balance – we are on an environmental knife’s edge. Governments the world over are struggling to provide adequate and appropriate leadership to set us on a path that will ensure sustainable peace and harmony. The role that the MST community plays is thus pivotal in building bridges to and for a sustainable future.

As we deliberate our role in building a sustainable future, let us be mindful of our responsibilities as researchers and creators of new knowledge and understandings in the context of MST education.

The collection of papers in these proceedings is the result of commitment, dedication and hard work. I wish to express my gratitude to the authors, the reviewers and the conference organisers for all that they have done in the publication of this work. The proceedings reflect a diverse and rich research culture in the fields of MST education in Southern Africa - the SAARMSTE community is vibrant and dynamic.

I also wish to take this opportunity to thank our funders who have given so generously in supporting SAARMSTE to achieve its aims and objectives. Without their assistance this conference and this publication would not have been possible.

Marc Schäfer
SAARMSTE President
January 2011
# TABLE CONTENTS

Mathematics Teacher Learning in Data-Informed Practice: Preliminary findings from an ongoing study  
Million Chauraya¹ and Karin Brodie²  

“I can’t draw zero”: Grade 3 and 4 learners’ dilemmas with structure in multiplication by zero  
Zonia Jooste  

To What Extent Do Student’s Conceptions Of Proof Influence The Nature Of Proofs They Produce In Elementary Number Theory?  
Kenneth M. Likando¹ Mapula G. Ngoepe²  

Challenges of teaching and learning linear programming in a multilingual classroom  
Mahlodi J. Maredi¹ Anthony A. Essien²  

The mathematics of water: Insights from a Grade 8 lesson episode on conservation  
Lesego Brenda Mokotedi  

Uncovering meanings of a term by looking at the way it is written  
Willy Mwakapenda  

The use of language in the Learning of Geometry  
Themba Leslie Ndaba  

Analyzing Socio-cultural Values Influencing the Development of Mathematics Teaching Skills of UNISA ODL Pre-service Teachers  
Lovemore J Nyaumwe, Mapula G Ngoepe  

The perceived impact of an ACE Mathematics professional development programme  
Tom Penlington  

Mobile technology and the autonomous learning of mathematics  
Duncan Samson¹ Helmut Linneweber-Lammerskitten² Marc Schäfer ³  

Exploring teaching proficiency using elements of enactivism as an analytical tool: a Nambian experience  
Gervasius H. Stephanus and Marc Schafer  

An exploration of the perception of teachers about the training of mathematics teachers for the middle school  
O. D. Thibodi, F. N. Kwayisi  

An investigation into learner errors whilst calculating division in problem solving  
Thami Tokwe, Fezeka Mkhwane  

A comparison of teacher and learner perspectives on the use of isiXhosa as in the teaching and learning of school mathematics and science  
Monde Mbekwa and Vuyokazi Nomlomo  

What effect will dialogical argumentation have on Grade 9 learners’ conceptual understanding of selected meteorological concepts when used as an instructional method in a science classroom in the Western Cape, South Africa  
Alvin Daniël Riffel¹ Meshash Ogunniyi² Keith Langenhoven³  

Using drama to teach science: Exploring and occupying the ‘empty space’  
Martin Braund  

Integrating Education for Sustainable Development into science teaching: Swazi secondary teachers’ perceptions  
Turu Dube¹ Fred Lubben²  

Exploring teachers’ and learners’ understandings of nature of scientific inquiry (NOSI): the validation of research instruments  
Washington T. Dudu¹ and Elaosi Vhurumuku²
### Challenges in conducting research into the effects of an argumentation-based instruction on grade 10 learners’ understanding of the causes of pollution at a river site
Ruben Magerman, Meshach Ogunniyi, Keith Langenhoven
155

### South African Science Teachers’ Conceptions of Teaching Science and of the New Curriculum
John McBride and Dale Taylor
163

### Teacher Roles in Implementation of the Natural Sciences Curriculum of the National Curriculum Statement
T.G. Mere and F.N. Kwayisi
168

### Teachers as promoters of Environmental Education: A case study of three Lesotho schools
Lira Molapo, Michèle Stears
178

### Learning to be a Scientist: Are Pupils’ Classroom and Out of Classroom Experiences Synchronised?
Vongai Mpofu, Zvikomborero Muropa, Lovemore P. Kusure
186

### Using on-line discussion forum to explore pre-science teachers’ arguments about their role in developing language in science classrooms
Gaobolelewe Ramorogo
187

### Secondary school teachers’ perceptions of practical work in biology in the oshana education region
Lahja L. Nghipandulwa, Hileni M. Kapenda, Choshi D. Kasanda
189

### Enhancing Life Sciences teachers Pedagogical Content Knowledge (PCK) in well-functioning ecologies of practice
Neal T. Petersen, Josef de Beer
194

### The champion in every one of us: Empowering rural communities through ICT
Branwell Isaacs
208

### Understanding the Technology Knowledge of Office Data Processing teachers in the context of ICT-based classrooms in FET colleges
Adegbenro, Bolaji J. Janet, Mwakapenda, W.J, Olugbara, O.O
220

### The application of concepts in electricity through Design activities during a Technology Education Class
Ravin Chitranjan Gayadeen, Deonarain Brijlall
226

### The effect of Advanced Certificate in Education technology training on in-service teachers’ professional development regarding their knowledge and understanding of technology
Mishack T Gumbo, Moses Magkato
237

### A critical reflection on curriculum review of technology education in South Africa
Gumbo M.T.
245

### Factors contributing to poor performance of FET college students in Engineering Graphics and Design
Makgato M
254

### A Reconnaissance study into Technology teaching practice in Limpopo Province schools
Tlou Albert, Mapotse; Mishack Thiza, Gumbo
269

### Perceptions of student teachers at the North West University (Mafikeng Campus) about the importance of technology education
A.Mutsvangwa and F. N. Kwayisi
283

### The mentor-student teacher interaction in times of major curriculum change: Views on the nature of professional support
Fred Lubben; Martin Braund; Zena Scholtz; Robert Koopman; Melanie Sadeck; Beatrice Thuynsma
289
The Reflective Teacher Journal: What does it reveal about teachers’ beliefs and professional growth?
Rose Spanneberg ................................................................................................................ 299
Early Career Secondary Science Teachers’ Classroom Practices
Dale Taylor¹ Shirley Booth² Tony Lelliott³ ......................................................................... 310
The use of Analogies in Chemistry Teaching in Mozambique
Jose Arão,¹ Emilia Afonso Nhalevilo² ................................................................................ 319
Effects of Dialogical Argumentation Instruction (DAI) in a Computer-Assisted Learning (CAL) environment on grade 10 learners’ understanding of concepts of chemical equations
Frikkie George, Moshach Ogunniyi, Keith Langenhoven .............................................. 323
The feasibility of M-Learning (mobile learning) into the chemistry curriculum of high schools in Mafikeng district of South Africa
Mohini Joshi¹ Kiran odhav² ............................................................................................... 334
Topic Specific Knowledge For Teaching As A Construct For Investigating The Development Of Chemistry PCK In Pre-Service Science Teachers
Madlivane Elizabeth Mavhunga ¹ Marissa Rollnick ² .......................................................... 340
Investigating the nature of epistemological access afforded by a first-year chemistry intervention programme
Duncan Samson¹ Joyce Sewry² Sue Southwood³ .................................................................. 349
Evaluation/ Impact assessment study of the Chemistry student laboratory project
Thabo Tholo¹, Monye Ncoane² .............................................................................................. 356
Physics students’ experiences of force and algebraic signs in 1-dimensional motion in mechanics
Nadaraj Govender and M.A. Good .......................................................................................... 366
Mathematics Teacher Learning in Data-Informed Practice: Preliminary findings from an on-going study

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The results presented originate from an on-going teacher professional development study which uses the notions of data-informed practice and professional learning communities. Five mathematics teachers in one high school worked with the researcher on a number of professional development activities that used data about learners’ errors on mathematics tests. The paper presents results pertaining to the teachers’ conversations in analyzing learners’ errors related to rational number test items. The results show that, through the conversations, the teachers developed an understanding of errors as indicators of deeper misconceptions; deepened their subject content knowledge about certain aspects of rational numbers; and developed a deeper conceptual understanding of how equivalence of rational numbers underpins the algorithms for adding and subtracting fractions, as well as the connections among common fractions, decimals and percentages. The findings support the claim that engaging teachers in job-embedded teacher professional development programmes that involve sustained collaboration on activities that use data from their classroom contexts can lead to significant teacher professional learning.

Introduction

Contemporary research in teacher professional development focuses mainly on professional development that emphasizes teacher learning (Wilson & Berne, 1999). Professional development in which teachers learn in practice is regarded as more likely to result in lasting changes in practices (Kazemi & Hubbard, 2008). Characteristics of such professional development include: being school-based and embedded in teachers’ work; collaborative and providing opportunities for interaction with peers; focused on student learning; and being continuous and coherent rather than fragmented (Abdal-Haqq, 1995). The effectiveness of such professional development programmes is believed to lie in ensuring adequate teacher collaboration to produce shared understanding, a focus on problems of curriculum and instruction, and being of sufficient duration to ensure progressive gains in knowledge (Little, 1993). In spite of the advocacy for such professional development programmes, little is known about what and how teachers learn in such professional development opportunities (Wilson & Berne, 1999).

The findings reported in this paper arise from an in-service, school-based teacher professional development initiative that meets the characteristics described above. The study uses the notions of data-informed practice (Earl & Katz, 2002) and professional learning communities (Jackson & Tasker, 2002), and is based on the argument that data-informed practice, as a form of teacher professional development, supports teacher learning in both subject content and pedagogical content knowledge. In this paper we draw on preliminary findings from the study to address the question: What and how do teachers learn in data-informed practice?

The study uses Wenger’s (1998) theory of learning as social practice as the guiding framework. The theory was found to be suitable because the study involves a group of five mathematics teachers in one high school, constituted as a community of practice,
collaboratively using data from their classroom contexts to develop their professional knowledge.

The conceptual framework and design of the study

The main concepts in the study are data-informed practice and professional learning community. Data-informed practice is the process of “transforming data into knowledge and blending it with wisdom for use in planning and decision making in schools” (Earl & Katz, 2002, p. 1004). In a school context data-informed practice involves teachers collaboratively engaging in professional learning conversations that are designed to make sense of various forms of evidence which can result in changes in learners’ learning (Brodie, Shalem, Sapire, & Manson, 2010).

A professional learning community is “a group of teachers sharing and critically interrogating their practice in an on-going, reflective, collaborative, inclusive, learning-oriented, growth-promoting way” (Stoll & Louis, 2007, p. 2). In the study the teachers collaborate in analyzing classroom data. The goals of the collaboration include: challenging practice, focused professional learning, deepening understanding, proposing and testing solutions, and improving the quality of classroom instruction (Katz, Earl, & Jaafar, 2009).

The activities of the professional learning community in the study are guided by what Timperley, et.al. (2007) refer to as the teacher inquiry and knowledge-building cycle (Figure 1 below).

Fig. 1: Teacher inquiry and knowledge-building cycle to promote valued student outcomes
(Timperley, et al., 2007)

The specific activities that the mathematics teachers engaged in are: testing and analyzing their learners’ errors on two teacher designed tests; interviewing learners about their errors; identifying important learning needs to focus on; using the information to design and teach innovative lessons for addressing the identified learning needs; testing and interviewing learners again; and reflecting on the impact of the lessons. The activities were adopted from the Data Informed Practice Improvement Project (DIPIP), an ongoing teacher professional development project based at Wits University (Brodie, et al., 2010).

The qualitative case study extended over a period of nine months in 2010. The five teachers and the researcher, who acts as a facilitator and ‘critical friend’ (Katz, et al., 2009), met once a week in the school to work on the activities. In the activity the teachers, tested learners, analyzed the demands of each test item, and the errors made by the learners. Each teacher
interviewed at least five learners from his or her class on specific errors they made in the test. By analyzing all the data the teachers identified the following critical mathematical concepts for their learners: the connections among the different forms of rational numbers; the order of operations in expressions with multiple operations; ratio; place value; positive and negative integers; and exponents. For the purposes of this paper preliminary findings pertaining only to the teachers’ conversations about the concept of rational numbers are presented.

For the rational number test items the teachers analyzed the learners’ pass rates per test item; the observed errors on each item; and notes from learner interviews. Their analysis was based on test items on which the average pass rate was less than 40% of all the learners. The selection of learner errors for analysis involved both the teachers and researcher going through all the test scripts identifying the most common errors. This was followed by a discussion and agreement on which errors to analyze. The items, learners’ errors and names of learners who made each error were then summarized on data walls, which were charts displayed for reference purposes during the error analysis conversations. Six learners were interviewed about their errors on rational numbers items. Each interview was audio-recorded.

In the paper we analyze how the data-informed conversations (Earl & Timperley, 2008) about their learners’ errors fostered the teachers’ understandings of their learners’ learning needs in relation to the concept of rational numbers, and how such understandings led to the deepening of the teachers’ own subject content and pedagogical content knowledge (Shulman, 1986). In their conversations the teachers were guided by templates adapted from the DIPiP project.

Data and data analysis

The data which the teachers analyzed on the concept of rational numbers is summarized in Table 1 below. In the Table the average pass rate refers to the percentage of learners who got the item correct out of the total 52 learners who wrote the test.

From the six learner interviews: two learners did not know the difference between $0.54$ and $\frac{24}{48}$. Both could not give examples of common fractions, decimal fractions and whole numbers. One of them wrote whole numbers when asked to give examples of common fractions. On addition of common fractions and mixed numbers, one learner knew about the lowest common denominator (lcm) and referred to it as a rule. When asked to find the lcm of $\frac{8}{24}$ and $\frac{4}{8}$ she gave the highest common factor (hcf) instead of the lcm. Two learners had used calculators to add common fractions and gave decimals as answers. Both said they did not know any other way of adding fractions. Two learners could not say what a number such as $2\frac{1}{3}$ was, and could not describe its structure. Noteworthy is that none of the learners in both classes realized that in the item: $\frac{15}{24} + \frac{3}{8} - \frac{1}{4}$, there was no need to find the lcm because the last two fractions are equivalent to each other.

The teachers’ conversations focused on the conceptual ideas connecting common fractions, decimals and percentages, and the conceptual meanings of the algorithms for addition and subtraction of fractions. The conversations revolved around how the notion of equivalence underlies the connections among common fractions, decimals and percentages, and the algorithms for adding and subtracting fractions (Lamon, 1999).

Table 1: Test data used for the concept of rational numbers
which underpins the learning of other concepts, and without whose mastery the learning of other concepts is difficult.

From the analysis of learners’ errors on rational number items the following concepts and skills were identified as critical for the learners: expressing common fractions as decimals or percentages, and vice versa; addition and subtraction of fractions; mixed numbers; recurring decimals; and the notion of the lowest common denominator. Further analysis of these critical concepts and skills resulted in the identification of conceptual connections among equivalent forms of rational numbers as the ‘high leverage concept’ which was critical for the learners.

1 The term ‘high leverage concept’ was adopted from the DIPIP project. It refers to a mathematical concept which underpins the learning of other concepts, and without whose mastery the learning of other concepts is difficult.
In the following paragraphs we present some episodes which illuminate what and how the teachers learnt about rational numbers through the conversations.  

Episode 1: Understanding of errors as indicators of misconceptions.

One finding was that the teachers began to engage in discussions that included a focus on errors as indicators of deeper misconceptions among their learners. For example in question 1 (Table 1), learners gave answers that had the original digits ‘5’ and ‘8’. The following are some of the teachers’ responses to the researcher’s question: ‘What is the big misunderstanding here?’

Teacher 3: Any number, any co…, eh digi….eh decimal number has a comma and he puts a comma there between the two.

Re: Is that true for decimals also?

Teacher 3: Eh, eh part two these numbers must be expressed in percentage, then he puts the percentage sign.

Teacher 4: Write in the percentage form, she knows that when we write a number in a percentage they know the symbol for percent, so since we have decimals we just take the symbol and put it there.

Teacher 2: There I think there is the belief that ah five over eight has to be represented in its equivalent form because now still we have the ah five comma eight

The consensus from the conversation was that the possible learner misconception behind the observed errors could be a belief that the original digits in a common fraction do not change when the fraction is expressed as a decimal fraction or a percentage. The misconception was attributed to the use of base-ten fractions such as \(\frac{3}{16}, \frac{12}{100}, \frac{144}{1000}\) (Van De Walle, 2004) to introduce decimals and percentages in teaching situations. This led to the following statements:

Teacher 2: Eh I think as we are teachers, maybe we should take this example and another where they are disappearing like that.

Teacher 3: According to this eh change the examples when teaching.

The above conversation shows how the teachers began to link learner errors to possible misconceptions. Of interest was the ability by the teachers to link the learner misconception to their teaching practices, which could be a significant contribution to their pedagogical content knowledge.

Episode 2: Deepening subject content knowledge.

The teachers also had conversations that involved their subject content knowledge. Question 2(i) generated quite an extensive discussion about recurring decimals. The discussion centred on how the learners were expected to answer the task. In the discussion one teacher challenged another teacher to explain to the group how learners were supposed to answer the task.

Teacher 3: “J”\(^5\) can you explain to us how to express that...

---

\(^2\) In the episodes we refer to the individual teachers as ‘Teacher 1, Teacher 2, Teacher 3, Teacher 4, Teacher 5’, and ‘Re’ to refer to the researcher.

\(^3\) Misconceptions are learners’ conceptions, based on earlier acquired knowledge, that produce a systematic pattern of errors (Nesher, 1987).

\(^4\) Base-ten fractions are normally the first examples that learners encounter in learning about decimal fractions.

\(^5\) “J” refers to Teacher 5.
Teacher 2: As a common fraction
Teacher 5: Aah I don’t know the recurring... its the one “B” gave to the learners... I don’t give them the recurring in class (laughter).

One teacher (Teacher 3) then volunteered to go and find out how to do it and explain to the group the following day. However Teacher 5 continued to seek clarification about the meaning of \(0.5\) from the group and admitting that she did not teach this topic:

Teacher 5: Its zero comma five four five four, ne?
Teacher 3: Aaa, Aaa
Teacher 5: Or four four four?
Teacher 3: Four four
Teacher 5: But to my, no I am telling the truth, I didn’t give the learners the one that have a recurring

Re: No after tomorrow you should be able to give them
Teacher 5: Ja, but but in grade ten we don’t use the recurring\(^7\)
Teacher 3: These are the sums they avoid in most cases, why do you avoid them? (laughter)

The ensuing conversation led Teacher 5 to acknowledge that even in Mathematics Literacy recurring decimals needed to be taught. The solution to the test item was later explained by Teacher 1 who was not present when this conversation was held.

The conversation highlights how a learning opportunity was created and supported, without being threatening, in developing the teachers’ subject content knowledge. The conversation also illuminated the possible development of relationships of respect and challenge, which is important for productive data-informed conversations (Earl & Timperley, 2008). Seeking clarification from others could be an indication of developing confidence and trust in others. One of the prerequisites for real new learning is a conscious awareness and acknowledgement of what one doesn’t know (Katz, et al., 2009).

**Episode 3: Developing conceptual understanding.**

In the conversation about the conceptual meanings of the algorithms for adding and subtracting fractions the researcher used a variety of probing questions and, in one case a cake-cutting activity, to guide the teachers’ thinking. The following excerpts highlight how the conversation around the task \(\frac{15}{24} + \frac{2}{6} - \frac{1}{4}\) helped the teachers develop the relevant conceptual knowledge. The researcher asked the question “Why do denominators have to be the same, why do we need an lcd when we are adding fractions, why is it necessary?”

The following responses show that the teachers initially understood the lcd as no more than a condition for adding or subtracting fractions.

Teacher 4: Before we add we have to, the denominators have to be the same, to be equal.
Teacher 5: To write it in equivalent form.
Teacher 1: I think its very necessary because when you add or subtract fractions your denominators must be the same so that you can concentrate on the numerators.
Teacher 2: When denominators are the same then we can add or subtract numerators
Teacher 1: It becomes, I think it makes your method to be simple, to be simpler.

---

\(^6\) “B” is Teacher 1 who was not present when this conversation was held.

\(^7\) The Grade 10 class was doing Mathematics Literacy.
Teacher 2: You are dealing with fractions that are nearly identical.
Re: What do you mean?
Teacher 2: In terms of ah maybe when you are given a whole you want to divide the whole so when the denominators are the same it will be easier for you to work with the numerators.
Realising that the teachers were not very explicit about the need for fractions to be of the same size, for addition and subtraction to be possible, the researcher used a model of cake-cutting to illustrate how, in \( \frac{1}{6} + \frac{1}{6} \) it was necessary to rename \( \frac{1}{6} \) as \( \frac{2}{12} \). The following are some of the excerpts in the conversation in which Teacher 1 was asked to cut off a quarter and then an eighth of the cake. The researcher posed the question “What fraction of the whole cake has been removed?” The following were some of the responses.
Teacher 1: Two over, one over.
Teacher 1 & Teacher 5: Two over eight, which is one over four.
Teacher 3: Three over...
Teacher 1 & Teacher 5: Ke ena\(^8\) three over eight.
Teacher 3: Three over eight.
Re: How did you get three over eight?
Teacher 3: You count how many parts are there, they are three
Re: You see where the challenge is, you can’t add this and that as they are because these are of two different sizes, you need to cut into the same size. You can only add or subtract fractions if they are of the same size.
Teacher 1: So that’s what we have to explain to learners?
Re: Exactly, in other words right at the beginning before you start saying find a common denominator, just play around with exactly what we were doing here.

From the conversation the teachers were able to connect the lowest common denominator (lcd) to equivalence of fractions in addition and subtraction of fractions.

The conversation highlights how the teachers accessed a conceptual understanding of the equivalence in addition of fractions. The teachers initially had an idea of the notion of equivalence, but could not explicitly link it to the idea of equal-sized fractional parts. Such knowledge is necessary when developing learners’ initial understanding of equivalence of fractions. One teacher pointed this out, although in the form of a question. This teacher’s remark could be an indication of the teachers’ awareness of learners’ learning as the focus of the activities.

**Episode 4: Making conceptual connections among common fractions, decimals and percentages.**

The conversation for making connections between common fractions and decimal fractions followed a similar type of questioning by the researcher. It was evident that whilst the teachers could express base-ten fractions as decimals or percentages (Episode 1 above), they were not making connections with other fractions such as \( \frac{3}{4} \). To make the connection the researcher asked the teachers to express the following decimal fractions as common fractions: \( 0.5; 0.25; 0.375; 0.4567 \). The teachers realized that denominators were multiples of ten.

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\(^8\) Ke ena means ‘it is this one’
When asked to express a common fraction such as \( \frac{5}{8} \) in its equivalent form as a base-ten fraction, the teachers were able to work out that: \( \frac{5}{8} = \frac{625}{1000} = 0.625 \). Realizing that this was an alternative way of expressing common fractions as decimals, one of the teachers remarked:

Teacher 1: Okay, heh, M…, huh, so which one is the simplest?

The remark led to further discussion of how the ‘two’ approaches were virtually the same.

Similar reasoning and strategies were used to develop the teachers’ understanding of the connection between common fractions and percentages. An understanding of a percentage as a fraction with denominator of 100 led to statements such as: \( \frac{5}{8} = \frac{625}{100} = 62.5\% \). At this point one teacher asked a question which generated the following conversation:

Teacher 5: M… if I say five over eight I want to convert it to percent, if I say multiply by hundred am I wrong?

Teacher 1: You are not.

Re: Why do you have to multiply by hundred?

Teacher 5: Converting into a percentage.

Re: What is a percentage?

Teacher 5: Percentage is hundred, so if I say five over eight multiply…

Re: Percent, the word percent, what does it mean?

Teacher 3: Out of hundred

Re: Percent, cent, what do you understand by the cent in percent, where does it come from?

Teacher 3: Is a pace laughter.

Re: It comes from century century is hundred right so cent comes from century which means hundred, per means out of, so percent means out of hundred.

At this point the researcher showed how \( \frac{5}{8} \), is the same as \( \frac{5}{8} \times 100\% \).

The conversation helped the teachers develop a deeper understanding of a percentage as ‘out of a hundred’ (Lamon, 1999) and how percentages are connected to equivalence of fractions. The teachers’ attempts to adhere to the algorithm of ‘multiply by hundred’, even without understanding why it works, could be attributed to the tendency to derive comfort in correcting applying algorithms even without understanding why they work. While challenging beliefs and practices is critical to learning in collaborative inquiry, ‘pushing’ participants out of “their comfort zones” (Katz, et al., 2009, p. 94) is not easy. The teacher who initiated the conversation seemed to be satisfied with the algorithm of ‘multiply by hundred’, and saw little value in first expressing the common fraction in its equivalent form with denominator hundred in order to express it as a percentage. The teacher seemed to be struggling to reconcile her new understanding of percentages with her existing knowledge of an algorithm. The existence of such situations in teacher professional learning is important as they serve to deepen professional knowledge (Katz, et al., 2009).

Discussion

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9 The teachers were apparently more familiar with the algorithm of successively dividing the numerator by the denominator when expressing a common fraction as a decimal fraction.
The results highlight some important issues about data-informed practice as a professional development approach. The findings indicate how learners’ test data was transformed into structured learning opportunities for the teachers (Brodie, et al., 2010). In their conversations the teachers frequently linked the developing ideas to their pedagogy in the classroom, which could be an indication that the teachers began to realize the implications of their gains in subject content knowledge on their practice. The teachers also began to show an understanding of learners’ errors as indicators of possible misconceptions. These preliminary findings indicate significant teacher learning in both subject content and pedagogical content knowledge, which are both critical components of teachers’ professional knowledge.

The findings also highlight the significance of some implementation features to the teachers’ learning in the professional development initiative. The use of test data originating from the teachers’ classroom situations could have created a sense of relevance of the activities to the teachers’ immediate professional needs, and hence contributed to the teachers’ commitment to the activities. The teachers’ frequent reference to learners’ learning could be an indication of their awareness and appreciation of the learning focus (Katz, et al., 2009) of the activities. The findings also indicate the development of relationships in which the teachers felt comfortable to challenge each other respectfully in the conversations. The teachers began to develop a level of trust and confidence in each other which enabled them to admit weaknesses and make explicit whatever they were not knowledgeable or clear about. The conversations were also characterized by frequent laughter and humour which are indicators of the establishment of community. The implementation features highlighted above are important for teacher learning in professional learning communities and productive data-informed conversations.

Although the paper was restricted to findings pertaining to the teachers’ conversations about one mathematical concept, it has highlighted some pertinent aspects of data-informed practice as a teacher professional development approach. The preliminary findings indicate that the teachers’ collaborative inquiry into data about their learners’ errors is inseparable from their professional learning (Katz, et al. 2009). Using the findings we make the claim that job-embedded teacher professional development programmes that involve teachers in sustained collaboration on activities that use evidence from their classroom contexts, can lead to significant teacher professional learning.

References


“T can’t draw zero”: Grade 3 and 4 learners’ dilemmas with structure in multiplication by zero

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Abstract

This MEd research study focused on the conceptions and misconceptions that primary school learners (grades 3 to 6) experienced with the concept of zero and how teachers contribute to learners’ misconceptions especially with regard to multiplication and division with zero. The study intended to answer the question, ‘Why do learners and teachers experience problems with the concept of zero?’ The research was conducted in an interpretive, qualitative approach and data was collected in three phases from 2007 to 2009 involving grade 3 and 4 learners in a rural school in the Western Cape, grade 5 and 6 learners in a rural school in the South Cape, grade 5 learners in a local school in Grahamstown and Eastern Cape teachers on a BEd in-service and an ACE Mathematics course conducted by RUMEP. The research instruments
entailed a mental calculation questionnaire for assessing knowledge of the four basic operations completed by grade 3 to 6 learners, written responses and elaborations acquired in a questionnaire concerning subtraction, multiplication and division with zero completed by grade 5 and 6 learners, eight BEd and thirty-nine ACE teachers. Teachers also completed an individual questionnaire requiring indications of teachers’ general knowledge concerning the concept of zero. The data collected included written responses and photographs of the grade 3 and 4 class regarding multiplication with zero obtained during a classroom intervention session and data obtained in a semi-structured focus group interview conducted with a group of three grade 5 learners and the teachers in the BEd group. The results of the study imply that both learners and teachers lack knowledge and understanding of the concept of zero especially concerning multiplication and division with zero. Findings also revealed that teachers’ general knowledge of zero is inefficient and effective teaching and learning of the concept of zero is insufficient or non-existent. In this paper I report on findings reflecting grade 3 and 4 learners’ abilities to solve division and multiplication with zero problems reflected in a mental calculation task and multiplication problems with natural numbers and zero during a classroom intervention session. The emphasis is specifically on the structure that learners’ imposed on multiplication with natural numbers and how the structure obscured learners’ sense making of multiplication with zero.

Introduction

In mathematics, the understanding and application of the concept of zero as a number and placeholder had been contentious issues throughout many centuries in different cultures. Various studies reported on problems that ancient mathematicians experienced with the concept of zero, e.g. Gullberg (1997), O’Connor & Robertson (2000), Anthony & Walshaw (2004), Quinn, Lamberg & Perrin (2008), etc. The history of the development of the concept of zero is characteristic of the separation of conceptual and procedural knowledge. Ancient mathematicians took centuries to discover the meaning and important use of zero in the number system. The Greek mathematician Archimedes totally disregarded zero and Aristotle wanted to declare zero unlawful because it bungled his calculations (Ball, 2005).

The concept of the null or empty set containing zero elements is not a novel or complicated idea but is an abstract concept for young learners resulting in them overlooking the existence of zero and considering zero as nothing (Anthony & Walshaw, 2004 and Reys & Gouws, 1975). The diminishing conception of zero succeeds from primary school to secondary school learners and even pre-service and in-service teachers. Levenson, Tsamir & Tirosh (2007) concluded that the number zero’s behaviour differs in many cases from other numbers and learners willingly separate zero from the set of counting numbers.

Reid (1956) reckoned that we do not usually think of or engage with zero as a number because we do not usually deal with zero as a number. To be classified as a number, numerals should associate and combine with already existing numbers. For zero to be assigned equivalent grading as the existing numerals, its behaviour in the four basic operations should be understood. This was first done by Indian mathematicians round about 773 AD. The grade 3 and 4 learners in this study experienced no formal teaching and learning of the concept of zero and the teacher did not provide them with uninformed rules to memorise zero’s behaviour in multiplication and division as it often happens in higher grades. The intuitive model of repeated addition applied by the learners to represent understanding of multiplication interfered with the learners’ conceptual understanding of multiplication by zero.
Methodology
This research was performed in an interpretive approach with the main concern sense-making of the personal world of the experience of human beings (Cohen & Manion, 2000) by observing learners’ (and teachers’) interactions, perceptions and expressions in constructing meaning of the concept of zero in multiplication and division problems in their authentic learning and teaching environments. The theory of constructivism underpinned the research with the acknowledgement that learners construct meaning in socio-historical contexts and assimilate new meaning into their existing knowledge structures (Clements & Battista, 1990). The emphasis was on profound meaning construction through interaction and observation of learners’ (and teachers’) thinking processes and performances in an interpretive, practical, reflective and qualitative knowledge-seeking endeavour. The intension was to identify emergent patterns from which I produced generalisations (Connole, 1993).

The grade 3 and 4 learners in this study were learners in an Afrikaans medium, multi-grade class at a rural school in the Western Cape that was one of thirty-eight schools engaged in a three-year numeracy and literacy project conducted from 2006 to 2008 by a university in the Western Cape. During the duration of the project two teachers per project school were expected to enrol for a part-time, two-year primary literacy and numeracy ACE course conducted by the university. The class teacher was one of the two teachers at the school who were on the course. The school was one of twelve schools that I supported as field worker and mathematics education specialist in this project. The grade 3 and 4 learner data was collected in 2008 during Stage 1, the pilot study, during classroom support visits which occurred twice a month at this school because the school is only about 70 km outside Cape Town. The class teacher co-facilitated and assessed the mental calculation test and also co-facilitated the classroom intervention teaching and learning session, which took place during a follow-up school visit.

The mental speed test questionnaire required of individual learners to complete four tests each involving thirty questions requiring instant written solutions on the four basic calculations. Learners were allowed one minute to complete each of the four tests and the completion of the entire test took about 5 to 6 minutes. Two of the thirty mental multiplication and division calculation questions involved multiplication with zero as the multiplier and multiplicand, i.e. 4 x 0 and 0 x 5 and division with zero as the dividend and the divider, i.e. 0 ÷ 7 and 5 ÷ 0. For the classroom intervention session, learners worked in small cooperative learning groups in their respective grades. They were confronted with problems such as 4 x 4; 4 x 3; 4 x 2 and 4 x 1 written on the writing board and were requested to make drawings to illustrate procedural and conceptual understanding. The problem 4 x 0 was posed after they had solved the previously mentioned problems to avoid the recognition of patterns in the numbers in solutions and to allow learners to demonstrate authentic procedural and conceptual understanding of multiplication by zero. Learners were also expected to demonstrate their understanding of multiplication by zero through physical modelling of the problems by grouping themselves in front of the classroom after the pictorial models used to represent multiplication and instruction to develop understanding of multiplication by zero. Photographs were taken to provide evidence of the physical representations. Evidence of grade 3 and 4 learners’ illustrations and demonstrations of conceptual and procedural understanding of division with zero could not be collected due to time constraints.
Theoretical framework
The purpose of the study was to develop intensive understanding of learners’ and teachers’ errors and misconceptions in knowledge demonstration of the concept of zero in especially, multiplication and division tasks. For the analysis and discussion of grade 3 and 4 learner data I drew on learning theories concerning meaning construction of multiplication by zero through the application of intuitive physical structures to develop mathematically-based reasoning and thinking.

Kouba & Franklin (1995) suggested that learners explain what they do and display rules they invent using physical things or drawings. Interrogating learners’ thinking could assist in planning teaching and in eliminating errors. Fennema (cited in Ell, 2001) asserted that the development of insight into learners’ thinking and reasoning could assist teachers in making essential amendments in their teaching to facilitate new knowledge and learners’ understanding. Cooper, Heirdsfeld & Irons and Fuson & Smith (cited in Ell, 2001) maintained that the connection between thinking and recorded responses is imperative in mathematics. The practice of written procedures or the lack thereof could have an impact on learners’ construction of structures and their perception of numbers. Applying teaching practice based on the study of learners’ natural strategies could promote teacher change and inform classroom practice in which meaningful teaching takes place in a constructive sequence which allows learners’ strategies to develop into sophisticated thinking and reasoning. Bonotto, Freudenthal, Linchevski & Williams, Piaget, Bruner and Skemp (cited in Levenson, Tsamir & Tiros, 2007) maintained that formal mathematics should develop from informal, practically-based thinking and reasoning because interaction with physical activities elicits abstract thinking and reasoning. Levenson, Tiros, & Tsamir (2004:241) made a distinction between learners’ mathematically-based and practically-based accounts before and after formal instruction of multiplication, learners’ descriptions of multiplication without zero and their explanations for multiplication with zero.

According to Ell, Irwin & McNaughton (no date:199) learners’ thinking in solving multiplication problems could be determined through their replies to problems. Their choice of solving strategies is decided by the structure they enforce on the problems and not on the actual mathematics rooted in the problems. Ell (2001) asserted that the construction of abstract structures or instinctive models can be described as a course of assembling a collection of understandings into a more influential and refined manner of thinking which is underpinned by the learning theories of Piaget and Vygotsky. According to Levenson, Tiros, & Tsamir (2004:214), the belief exists that primary school learners have a tendency of employing concrete materials or everyday life examples to demonstrate their mathematical reasoning or exploration of mathematical ideas in line with the theory of Piaget who classifies these learners’ stage of development as the “concrete operational stage”. Mulligan & Mitchelmore in Ell (2001) stated that a structure is based on the choice and use of a strategy and establishes learners’ view and understanding of numbers and the operations with numbers.

Various researchers claimed that young learners find arithmetic concerning zero difficult, that it is unlikely that learners will develop a total positive reception of zero prior to their second year of schooling, that primary school learners should not be engaged in calculations with zero and that the perception of zero does not develop satisfactorily until learners achieve the stage of formal operations (Inhelder & Piaget, 1969; Wheeler & Feghali, 1983; Oesterle in Anthony and Walshaw, 2004 and Semenza, Granà and Girelli, 2006). Cockburn (1999) and
Levenson, Tirosh & Tsamir (2004), e.g. suggested that work on the concept of zero should be included in learners’ early learning experiences. Meaning construction of zero as a number denoting nothing should be gradual and the learning experiences should be significant otherwise the misconceptions developed at an early stage could persist and be damaging to future development of number properties and future algebraic thinking and reasoning. Counting and calculating on a number line, reading temperature on a thermometer, using a measuring tape or scale for measuring length, mass and weight and capacity to perform accurate measurements, understanding rational numbers (decimals, e.g. 0,5) and integers, estimation and rounding off, construction of sine, cosine and tan graphs, etc. would not be possible without zero.

Discussion of results
The objective with this section of the study was to compare learner responses in mental calculations to written elaborations on calculations involving multiplication and division with zero. For the purpose of the study the responses to 4 x 0 and 0 ÷ 7 were considered. 17% of grade 3 and 50% of grade 4 learners supplied correct responses for the multiplication problem while 27% of grade 3 and 36% of grade 4 learners provided accurate responses for the division problem. Incorrect responses were stated as 4 x 0 = 4 by 83% of the grade 3’s and 50% of grade the 4’s and 0 ÷ 7 = 7 by 64% of grade 3’s and 50% of grade 4’s. The class teacher did not focus on teaching zero as a number in counting or calculation activities before the project intervention. My involvement in classroom support and in lectures made me realise that teachers do not teach the concept of zero explicitly because the curriculum does not expect them to. ACE teachers in this study declared, e.g. “I have never taught it in detail because I have never given the value of zero much thought. I assume they know”.

Grade 3 and 4 learner responses in 4 x 0 and 0 ÷ 7 could have been the result of speculation, i.e. the answer could either be 4 x 0 = 0 or 4 x 0 = 4 and 0 ÷ 7 = 7 or 0 ÷ 7 = 0, or guessing. The class teacher assessed the mental calculation tasks and after checking and analysing the results I observed that the teacher marked the response 4 x 0 = 4 correct in eight of the scripts. The teacher reported at the project conference held towards the end of September 2008 that it appeared as if learners of all ages have problems with the concept of zero, referring to her incorrect assessment of learners’ responses as reflected in figure 1 below.

During a follow-up classroom support visit the teacher and I provided learners with feedback on their mental calculation tasks. The teacher and learners agreed that we engage in a lesson
focussing on concept development of multiplication with zero because grade 3 learners performed weaker in the problem 4 x 0 (83% incorrect responses) than in 0 ÷ 7 (64% incorrect responses).

The learners worked in groups in their respective grades and were requested to make drawings to display understanding of multiplication without zero. The problem 4 x 0 was added after they have solved the previously mentioned problems. After learner feedback on these problems the researcher used the same calculations using models of equal grouping (composite wholes). This intervention was followed by learners’ physical modelling of the problems in front of the classroom.

Although the learners displayed good understanding of multiplication with single digit natural numbers, they were unable to make sense of multiplication by zero because they had not acquired the use of concrete picture models and symbolic notation to demonstrate effective procedural as well as conceptual understanding. The learners intuitively assimilated counting strategies into repeated addition to represent multiplication by illustrating pictorially, e.g. that 3 x 4 = 0 o o o + 0 o o o + 0 o o o = 12 or 3 x 1 = 0 + 0 + 0 = 3 thinking about multiplication as, e.g. ‘three times four’, i.e. a group of four individual objects repeated three times as seen in Figure 2.

![Figure 2: Grade 3 and 4 learners’ representation of multiplying single-digit natural numbers.](image)

This form of reasoning became problematic when the learners had to illustrate, e.g. 3 x 0 and 2 x 0 because the picture models used in the previous multiplication tasks did not suffice the operation with zero. Some learners recorded the solution to 2 x 0 correctly as 2 times 0 = 0 but incorrectly represented it using pictures and symbols as, for example 0 o x 0 = 0 and 0 o + 0 = 0. One group of learners asserted that they could not draw zero. Even the 17% of grade 3 and 50% of grade 4 learners who solved 4 x 0 correctly in the mental calculation task were not able to present effective models or representations to demonstrate conceptual understanding of 4 x 0, 3 x 0 and 2 x 0 as displayed in the examples below. Some groups could not structure drawings correctly and others were unsure or confused about the application of the addition and multiplication sign. In the examples shown in Figure 3 below, it is apparent that the learners intuitively knew that 2 times 0 is equal to 0, but they could not represent the problem diagrammatically as displayed in Figure 2. Representing multiplication by zero through repeated addition using groups of single objects appeared to have caused problems for these learners.

![Figure 3: Grade 3 and 4 learners’ struggle to represent multiplication by zero pictorially.](image)
Most of the grade 3 and 4 learners in this study realised that, e.g. $2 \times 0$ is 2 times 0, but were unable to represent the problem using the picture model. I represented the problems on the writing board using composite units, i.e. equal grouping in which a collection of single objects is regarded as one set so that the unit is countable (Mulligan & Wright, 2000 and Steffe, 1994).

The learners were then able to understand that $3 \times 0 = \square + \square + \square = 0$, i.e. three times zero or three zero’s indicated in three empty sets. When requested to model multiplication problems physically, the learners were able to organise themselves into equal groups to demonstrate understanding. One of the learners in the group who had to demonstrate $3 \times 0$ (grade 3 learners) told two of the learners to position themselves at the door while he took a seat at the teacher’s table. The learner suggested that I photograph the empty space in front of the classroom because $3 \times 0$ is equal to zero.

**Conclusion**

Learners who know that multiplication by zero results in zero do not necessarily have conceptual and procedural understanding of the concept. Responses to mental tasks should be connected to written calculations and elaborations for demonstration of understanding. Grade 3 and 4 learners in this study applied both practically-based diagrams (drawings of apples, triangles, squares and circles) and mathematically-based elaborations, e.g. ‘two times 0 = 0’ and stating the number sentence next to the drawings, i.e. $3 \times 2 = 6$ for three groups with two items each. None of the learners supplied rule-based explanations as learners often do in higher grades, e.g. ‘Everything that you multiply by zero is equal to zero’. The teaching of superficial, uninformed rules concerning calculations with zero should be avoided and learners should be allowed to construct their own understanding of calculations with zero. The application of equal grouping displaying composite wholes allowed learners to make sense of multiplication by zero. The development of effective multiplicative structure could assist learners’ in developing algebraic thinking in higher grades because the use of structure is imperative in organising and interpreting multiplicative conditions displayed in models, diagrams, tables and graphs (Mulligan, 2002). Grade 3 and 4 learners were not exposed to teaching and learning of the concept of multiplication by zero and therefore did not develop the necessary skill to represent multiplication by zero effectively. The learners were however able to construct meaning of multiplication by zero as suggested by Cockburn (1999) and Levenson, Tirosh & Tsamir (2004) through the application of effective multiplicative
structures. They competently assimilated, accommodated and equilibrated understanding of counting, addition, repeated addition and multiplication concepts to display practically-based and mathematically-based conceptual and procedural understanding of multiplication. The concept of zero was not present in their existing map of number relationships because they had no previous learning experiences of the concept. The dilemma with structure concerning multiplication by zero underlined the complicated behaviour of zero in calculations and the need for teaching and learning experiences that are active and exploratory for optimal cognitive development as suggested by Piaget (cited in Clarke, 2002).

Meaning construction of zero as a number denoting nothing should develop gradually from the Foundation Phase and learning experiences should be significant otherwise the misconceptions developed at an early stage could persist and be damaging to future development of number properties and future algebraic thinking and reasoning regarding zero.

On leaving the grade 3 and 4 classroom, I suddenly turned to a learner sitting close to the door and posed the question, ‘Six times zero?’ The learner replied, ‘Six . . . u-huh . . . zero!’ This was unfortunately my last visit to this school and as a result I was not able to observe and co-facilitate the learners’ understanding of division and I could also not arrange for opportunities to interview the learners or the teacher.

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To What Extent Do Student’s Conceptions Of Proof Influence The Nature Of Proofs They Produce In Elementary Number Theory?

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Introduction

The concept of proof forms a vital integral part of the syllabus in the training of mathematics teachers in colleges and universities. According to the National Council of Teachers of Mathematics NCTM (2000), a mathematical proof is a formal way of expressing particular kinds of reasoning and justification. Furthermore being able to reason is critical in the learning of all mathematics. By the end of high school, students are expected to be in a position to make use of mathematical reasoning to produce mathematical proofs, and to appreciate the value of such arguments (NCTM 2000). This seems to suggest that reasoning and proof should spread across all aspects of mathematics. Therefore student teachers need to possess this important skill to enable them to teach mathematics effectively in school.

Proof is widely acknowledged to be one of the most difficult aspects in the mathematics curriculum (Clements & Battista, 1992; Moore, 1994; De Villiers, 2004). Among the areas of the syllabus which students at college find difficult to understand is verifying the viability of claims through proving them algebraically. Studies, for example, (Usiskin, 1982; Healy & Hoyles, 2002; Gibilisco, 2005) point to abrupt introduction of formal proofs in colleges as one of the major causes of students’ difficulty in understanding proof. The research reported here was conducted at Copperbelt College of Education in Zambia. The difficulties that student teachers experience in proof are probably compounded by the fact that in the Zambian
curriculum for secondary mathematics there is hardly any inclusion of formal proofs, thus, denying students of the much needed smooth transition to college proof experiences later. This is despite the fact that at college the syllabus requires students to understand the ‘nature and place of proof’ and to develop some proficiency in mathematical arguments of deductive reasoning. It seems that students tend to find this to be a great challenge since their 0-Level mathematics background in proof enables them only to attain a very limited perspective of proof.

There is sufficient literature of research done on students’ difficulties in proof. Senk (1989) conducted a study in which proof-writing skills were tested among 1 520 in five states of the United States. Weber (2001:101) also investigated students’ difficulty in constructing proofs in abstract algebra. However, the extent to which the conceptions of proof influence ability to construct algebraic proof in elementary number theory has not been investigated.

The purpose of the study

The purpose of the study is to investigate the nature of difficulties that mathematics trainee teachers encounter in algebraic proofs at Copperbelt College of Education in Zambia. This is done with the hope that understanding the cognitive difficulties student trainees encounter in algebraic proofs could assist in evaluating strategies that could have a positive effect on students’ understanding of proof. The research question that this research answers is: To what extent do students conceptions of proof influence ability to construct algebraic proof in elementary number theory?

Theoretical framework

The theories of van Hiele and Piaget in the development of reasoning and proof as well as the works of Land and Nixon and the inherent levels of thinking forms the theoretical base of the study. By understanding students’ learning process we can understand their learning difficulties and think about possible solutions.

Research has linked the causes of students’ inability and misconceptions in understanding certain mathematical challenges to inappropriate thinking levels (see for example, Nixon, 2002; De Villiers, 2003; Stylianides, 2007). Evidence suggests that a student’s thinking level can affect their ability to cope with mathematical tasks. This is confirmed by De Villiers (2003:12) and van Hiele (1996:144) who believe that a child who has not yet achieved an appropriate level of thinking for understanding proof is unlikely to cope with instruction at that level.

The van Hiele theory claims that poor performance in the teaching of geometry (and algebra) is almost always as a result of neglecting students’ levels of thinking (Nixon, 2002:33). He further contends that proof oriented abilities first occur at van Hiele level 3 of thinking (Land, 1990:35). This seems to suggest that any student who is still below level 3 may find it virtually difficult to understand proof. Additionally, lack of attainment of level 3 could possibly result into many other inabilities in mathematical proofs.

Methods

A case study approach was used to bring about a better conception of students’ conceptions of proof. The participants were third year 35 male and 15 female mathematics trainee teachers. Data was collected by means of a questionnaire, a written test and an interview. Questions three to five of the questionnaire were used in an attempt to address the research question above. Students’ were asked to provide written descriptions about proof and what they thought it was. They were also asked to provide any algebraic mathematical statement
that they thought would require a mathematical proof. Consequently they were asked to name any axiom that they thought could be used in the proof of the named mathematical statement. In their written test, these conceptions of proof were confirmed since a number of them followed an empirical approach of argumentation. For example, in Proposition 1 Carol and Eric and in Proposition Two Carol, Peter and Thabo all used empirical examples as proof. The discussion of the findings follows.

Findings and Discussions

The findings will be presented by providing answers to three questions and Proposition I and 2

1. Explain your understanding of what proof is in mathematics.

From the students’ responses a total of four categories emerged. The categories were arrived at through what Miles and Huberman in Punch (2005:197) refer to as data reduction. This involved editing, segmenting, summarising and comparing the text answers which the students provided. These were coded into categories and patterns. Table 1 below provides a summary of the four categories:

<table>
<thead>
<tr>
<th>Categories</th>
<th>n = 50</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verification of the truth of mathematical results</td>
<td>27</td>
<td>54 %</td>
</tr>
<tr>
<td>Confirmation of correctness of mathematical results (using specific numbers)</td>
<td>10</td>
<td>20 %</td>
</tr>
<tr>
<td>A valid chain of deductive reasoning (using definitions or axioms)</td>
<td>10</td>
<td>20 %</td>
</tr>
<tr>
<td>No response (i.e. relevant answer spaces left blank)</td>
<td>3</td>
<td>6 %</td>
</tr>
<tr>
<td>TOTAL</td>
<td>50</td>
<td>100 %</td>
</tr>
</tbody>
</table>

From the table above, it is evident that the majority of the students (54%) were of the opinion that a mathematical proof constitutes verification of the truth of a mathematical statement. It is also noticeable from the table that twenty per cent of the students were of the view that proof constituted confirmation of results mainly by substituting specific numbers. This could be interpreted to mean that most of the students’ understanding of the concept of proof is largely empirical. That is, many students believe that verifying that a theorem holds in a specific instance or several instances is sufficient proof. It can be deduced that they do not really seem to understand what it means to prove something. These responses were not surprising as similar results have been found in other studies (for example, Weber, 2001:102; Sowder & Schappelle, 2002:190; De Villiers, 2003:6; Nyaumwe & Buzuzi, 2007).
2. Write down any algebraic mathematical statement (or theorem) in number theory that would need proof.

Students’ responses to this item were checked, edited and coded so that those that were correct and valid were arranged according to various groups of similarity. Nine categories emerged from the students written responses as shown in Table 2.

Table 2. Categories of algebraic mathematical statements produced by students.

<table>
<thead>
<tr>
<th>Categories</th>
<th>Number of respondents (n = 50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number properties of addition</td>
<td>7</td>
</tr>
<tr>
<td>Number properties of multiplication</td>
<td>6</td>
</tr>
<tr>
<td>Irrationality</td>
<td>9</td>
</tr>
<tr>
<td>Pythagoras’ theorem</td>
<td>3</td>
</tr>
<tr>
<td>Statements involving Mathematical Induction</td>
<td>3</td>
</tr>
<tr>
<td>Associative law</td>
<td>1</td>
</tr>
<tr>
<td>Statements involving Divisibility of numbers</td>
<td>1</td>
</tr>
<tr>
<td>Invalid statements</td>
<td>16</td>
</tr>
<tr>
<td>No response (i.e. relevant answer spaces left blank)</td>
<td>4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>50</td>
</tr>
</tbody>
</table>

The table above shows that 30 of the 50 respondents were able to write down correct and valid statements. Of the thirty responses, 13 were statements that involved simple properties on number systems such as ‘the sum of two odd numbers is even’ and ‘the product of two even numbers is even’. Nine produced statements that involved irrationality, for example: ‘Prove that the square root of two is irrational’. Three statements were on mathematical induction involving series of numbers. Sixteen respondents provided invalid statements and four of them did not give any response at all.

This item could also be linked to the item the six students responded to during the oral interviews in which they were required to provide statements that related to the ones they had just proved. Only two of them attempted to provide the answer while the rest could not. For example, the following excerpts provide an illustration:

(With reference to Proposition One which stated: For any positive integer n, if \( n^2 \) is even, then
n is also even)

Interviewer: Can you state another statement that is related to the one given?

Eric: If I have $2n$ I square it, I still get an even number where $n$ is any number from the set of rational numbers.

Jane: The product of two even numbers is even.

Peter: If $n$ is an odd number, then $n^2$ is odd.

From the above responses, Jane gave a correct statement while Eric’s response is just the same as the one given in the proposition but stated differently. The rest of the students could not raise a related statement.

From these data it can be conjectured that a large number (40%) of students in the respond to the questionnaire and four from the interviews who failed to produce the related statements simply indicated that several students do not have sufficient knowledge of mathematical statements and theorems that require mathematical proof. This could also probably be linked to their lack of understanding of what proof really is. This is because if they could not understand what proof was, it would possibly be difficult for them to know statements that needed proof in mathematics.

3. Write down any axiom that is essential in the proof of the statement you stated in Question four

Question 3 was meant to assess students’ knowledge of axioms used in proving mathematical statements. (An axiom may be defined as a basic mathematical truth or assumption that does not need any proof (Gibilisco, 2005:60)). Each of the fifty respondents was requested to suggest any axiom that they thought could be useful in constructing a proof of the statement they had given in Question 2. Responses were analysed to determine whether a suggested axiom was acceptable or not. An axiom was considered acceptable if it belonged to the field of mathematics and it would be relevant or useful in the proof of the respective statement or theorem mentioned by the student in Question 2. An axiom was considered unacceptable if it belonged to the field of mathematics but it would be irrelevant or not useful for the proof of the mathematical statement. An “axiom” was considered invalid if it was mathematically incorrect, meaningless and did not make any sense at all. The categories derived are presented in Table 3.

Table 3. Students’ responses showing suggested axioms to be used in proving their mathematical statements produced in question 2.

<table>
<thead>
<tr>
<th>Categories</th>
<th>n = 50</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptable axiom and relevant or useful</td>
<td>15</td>
<td>30 %</td>
</tr>
<tr>
<td>Acceptable axiom but irrelevant or not useful</td>
<td>7</td>
<td>14 %</td>
</tr>
<tr>
<td>Invalid axioms</td>
<td>13</td>
<td>26 %</td>
</tr>
<tr>
<td>No response (i.e. relevant answer spaces left blank)</td>
<td>15</td>
<td>30 %</td>
</tr>
<tr>
<td>TOTAL</td>
<td>50</td>
<td>100 %</td>
</tr>
</tbody>
</table>
The results revealed that only 30% of the responses were considered as acceptable, relevant or useful axioms. Fourteen percent of the responses were acceptable but irrelevant or not useful to the proofs of the stated statements. Interestingly, 26% of the respondents provided invalid axioms while a number of respondents (30%) did not write anything. The total percentage of those who wrote either an invalid axiom or no response at all was 56%. This represents the majority of the students. This could probably suggest that the majority of the students did not seem to even know the axioms that are used in proving mathematical statements. Stylianides (2007:291) observes that, in a genre of mathematical proofs, axioms and definitions are vital in establishing mathematical arguments.

Students’ inability to write correct axioms was also reflected in their written proofs where most of them failed to apply correct and relevant axioms. In the written “proofs” for Carol, Eric, Peter and Thabo, who had produced empirical proofs, there were hardly any axioms used. For example, Carol’s “proof” in figure 1 attests to this fact. These findings seem to suggest that generally, students possess only limited knowledge of axioms to be applied in proofs of propositions. Even those who have sufficient knowledge of axioms tend to find it difficult to apply them correctly and appropriately to specific proofs.

Students’ written ‘proofs’

The main purpose of the test in this study was specifically to provide an in-depth test to discover the nature of particular weaknesses and difficulties that students experience in proof construction as they relate to their conceptions of proof. Two propositions were chosen for this purpose.

Proposition 1: For any positive integer \( n \), if \( n^2 \) is even, then \( n \) is also even.
Proposition 2: The sum of two consecutive odd numbers is divisible by four.

In their written test, students’ conceptions of proof as discovered in the questionnaire were confirmed since a number of them followed an empirical approach of argumentation. For example, in Proposition 1 Carol and Eric and in Proposition Two Carol, Peter and Thabo (these are pseudonyms meant to protect students’ real identity) all used empirical examples as proof. Their purported proofs consisted of one or several numerical examples offering confirmation, yet incomplete evidence for the truth of the propositions. Eric’s proof provides a typical representation of this kind of argument.
Figure 1. Eric's "proof" of Proposition 1: For any positive integer \( n \), if \( n \) is even, then \( n \) is also even.

Analysis of Eric's "proof"

[1] \( n = 2p, \ p = 1, 2, 3, \ldots \) where \( p \in \mathbb{R} \). This representation is an appropriate way to start this proof. One can take it to mean: Let \( n = 2p \) where \( p \) is a positive integer. However, \( p \) has taken a dual role by being in the set of real numbers and as a natural number which is flawed. Besides, \( n \) is not well defined as the set to which it refers is not stated, but one may probably assume that it is implied from the proposition the student author is attempting to prove.

[2] then (i) when \( p = 1 \), \( n = 2(1) = 2 \) which is even. (ii) when \( p = 2 \), \( n = 2(2) = 4 \) which is even. (iii) when \( p = 3 \), \( n = 2(3) = 6 \) which is even. Like in the case of Carol, Eric took an empirical approach though he uses many instances (no matter how many specific cases one considers they will never prove a mathematical proposition or theorem). He fails to utilise concept definitions and other acceptable mathematical statements to reason with general deductive arguments. Apparent also in Eric’s “proof” was the absence of a link in individual inferences to further his arguments. This was probably due to lack of a concept image for proof.

Eric had managed to perform only one of the van Hiele proof abilities satisfactorily. This was the ability to begin a proof correctly including correct selection of a representation that was useful for the given case.

In proposition Two, Carol’s proof provides a typical representation of the other four similar types.
Figure 2. Carol’s “proof” of proposition 2: The sum of two consecutive odd numbers is divisible by four.

From Carol’s “proof” in figure 2 it is clear that axioms were not used and the mode of argumentation was empirical. The student probably believes that non-deductive arguments constitute a proof. According to Stylianides and Stylianides (2007) use of an empirical mode of argumentation does not constitute proof in mathematics. These findings probably suggest that these students lack a correct conception of what constitutes proof in mathematics. Differently stated, students did not seem to possess sufficient ‘concept images’ for doing proofs. Tall and Vinner (2003) define the term concept image as the total cognitive structure that is associated with a concept … This includes all the mental pictures and associated properties and processes relating to the concept.

The foregoing findings could also be linked to van Hiele’s theory on proof abilities. According to this theory, students begin to attain the development of proof abilities at level three (Land, 1990). While at level 4 students can construct proofs, understand the role of axioms and definitions, and know the definition of necessary and sufficient conditions. Consequently, it may be suggested in these results that students’ inability to perform proof tasks satisfactorily could probably be attributed to their not having had attained these van Hiele levels which are so crucial in developing proof abilities.

Conclusion and Implications

Some of the significant observations made here, are that students’ conceptions of proof were that they understood proof as a verification and confirmation tool. As a result, many of them applied empirical approaches in their written proofs. This was probably an indication that they had misconceptions of what constituted a mathematical proof. The findings also revealed that students did not have sufficient knowledge of the right set of accepted statements called axioms, which are critical in establishing deductive arguments in mathematics. Furthermore, students seem to have problems identifying which statements required proofs in mathematics. These conceptions could have led to the nature of proofs that they wrote. Most of their proofs were either empirical in nature or lacked axioms and definitions that were vital in the production of valid deductive arguments required in a mathematical proof. These findings suggest that students’ conceptions of proof do indeed influence the nature of proofs they produce.

The implications of the results obtained in this study on students’ misconceptions of proof cannot be overstressed. The findings of this research could be subjected to other interpretations. We acknowledge that many issues surrounding students’ nature of difficulties in algebraic proofs may not have all been captured here. Regardless of these limitations, the
findings of this study do still suggest some valuable implications that seem to have emerged.

It is recommended that lecturers, designers of curriculum and text book writers take note of these misconceptions students have so that the designing of curricula and teaching of proof related knowledge are done in manner that addresses them. It is further recommended that teachers and lecturers try as far as possible to relate proof to context instead of teaching it in abstract form.

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Challenges of teaching and learning linear programming in a multilingual classroom

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This study investigated the difficulties learners in Grade 11 experience in Linear Programming in a multilingual classroom and the strategies employed by their teacher in mediating knowledge in this topic. For data collection, classroom observation, a written test and interviews were used. Observation took three consecutive days followed by a written test and 4 learners were interviewed based on their solution from the test. The findings of this study revealed that the difficulties experienced by learners were: finding the constraints; plotting the constraints and identifying the feasible region; calculating the profit; translating from graphical to symbolic representation and engaging with long questions in Linear Programming. Lack of proficiency in the mathematics register contributed to the difficulties
experienced by these learners. Based on the findings, some recommendations were suggested.

Introduction

The aim of the study was to investigate the Grade 11 learners’ interpretation of Linear Programming problems. After 13 years of teaching and marking the Grade 12 end of the year examinations, I have always wondered why learners in multilingual mathematics classrooms experience problems in answering problems in Linear Programming (LP) which in some way are like contextual word problems (problems involving interpretation of language). South Africa has 11 official languages and there is a possibility that most of these languages may be represented in a single classroom, which I believe will make the teacher’s task to effectively teaching these learners to communicate mathematically even more difficult and challenging, but not impossible. Multilingualism is created by many factors like: (i) A learner attending a nearby school which does not offer the learner’s home language but another indigenous language as a home language. So this learner will learn a new home language, English as LoLT and learn mathematical communication. (ii) It may be created by issues like migration, people moving to places where there are resources. In the South African apartheid era the homelands were created such that each homeland had its own home language, people from the homelands came to rich provinces like Gauteng for jobs and security, and later they brought their families to their places of work. To most of these learners, as Herscovics and Kieran would put it, “translating a word problem into an equation is tantamount to translating it into a language unknown to them”. Herscovics & Kieran (1980, pp 572).

Pimm (1982) states that mathematics when written, often employs its own symbols yet when spoken, and comes out as English sentences. There is a distinction to be made between the spoken English or Ordinary English (O.E) and mathematical English (M.E). This raises questions about the English language proficiency of learners in multilingual settings. Are these learners proficient enough in written mathematics to confidently and correctly translate a Linear Programming problem into inequalities (constraints)? In Linear Programming, the problems are contextual, and there is a lot of reading and vocabulary in these problems. Learners need to be able to read mathematics word problems. Adams (2003, pp793) indicates in her study of reading mathematics that in mathematics texts, “the reader’s response to numerals is guided by what the words tell, Symbols are efficient means of showing what the words say and how the numerals are to be responded to according to the words”. One of the difficulties that the learners encounter is not doing the mathematics in the problems but the incorrect reading which results into a number of errors the learners commit in attempting to answer the questions (Helwig, et al, 1999).

One of the most important goals of the NCS is problem solving which includes the everyday situation of the learners in the mathematics classroom, because most students, outside of a school setting, face mathematics related problems in written form. It is therefore reasonable that students should be taught and be evaluated on their ability to solve written word problems (Helwig, et al, 1999).

Purpose of the study

The purpose of this study was to investigate the difficulties that learners in Grade 11 multilingual mathematics classroom experience in solving Linear Programming problems and how a teacher mediate these difficulties to enable epistemological access in LP. The following research questions were addressed:
1. What difficulties do learners face in multilingual mathematics classrooms while learning Linear Programming and why?

2. What are teachers doing to help these learners cope with reading the long contextual problems in Linear Programming?

Significance of the study

Research conducted on teaching and learning linear programming only focused on the deliberate use of home language by the teacher in a multilingual classroom. Not much has been done on the difficulties experienced by the learners in learning linear programming. In my search on research on the difficulties learners experience in LP, I found only one study conducted by Myandu (2010). The information above makes my study really significant.

The importance of the study is that it will inform practicing teachers about the type of difficulties learners experience in reading and interpreting contextual words, the study will inform me and other mathematics teachers about how to approach the topic and how to help the learners do well in Linear Programming. The study will also benefit teachers who have anxiety to teach the topic, so that they can teach it with confidence and more comfort. I believe the study will minimise the skipping of this section in the curriculum because the teachers will understand what to do in class. I also think it will inform the curriculum designers of the difficulties that learners experience in multilingual classrooms, and hopefully it will result in shifting the section Linear Programming from term 3 to term 2 after functions, since it is also LO2. Sections taught early in the year are better understood by learners more than sections taught later in the year, this is from my experience. 11.2.1(b); 11.2.8(a) & (b); 12.2.8 and 11.2.6(c) (NCS, Grade 10-12, General, 2003, Appendix 1, pp 17-19

Teaching and learning in multilingual classrooms

A number of studies which investigated into teaching and learning in multilingual classrooms have indicated that teaching and learning in multilingual classrooms is complex (Setati, 2008 & Adler, 2001). By multilingual classroom (in this study) is meant a class where learners and the teacher come to class with different proficiencies in two or more languages overall and where mathematics is learned in a language other than the first or home language. In such a class, learners not only learn mathematics in a language which is not their main and home language, but also are not necessarily proficient in the language of learning and teaching (LoLT). One of the complexities of teaching in such a classroom is that it is sometimes difficult for the teacher to strike a balance between paying attention to the mathematics and paying attention to the use of mathematical language (Setati & Barwell, 2009). Also, Research has also shown that it is also difficult for the teacher to discern or situate learners’ difficulties either as due to language limitation or due to lack of understanding of the mathematics, or even both (Essien, 2007. Doing this in a multilingual mathematics class is complex as it is not always a straightforward matter.

The language in education policy in South Africa allows for learners to study in any of the official languages in South Africa, research has shown that most learners prefer to study in English. According to Setati, Molefe & Langa (2008), this is because of the hegemony of English and the fact that English provides access to social goods (job, higher education, etc). Setati et al (2008) explored a strategy where learners were given maths tasks in both English and their home language. This study concluded that the strategy helped to make maths more
accessible to the learners in that the home languages work together with English. Other revelations were that deliberate use of learners language does not oppose English, but recognizes its political nature and that language becomes visible but invisible resource in the sense that while learners can draw on different languages at any time they want, it does not disturb their focus on the maths.

Linear programming is a linguistically dense topic in which many multilingual learners struggle to interpret and internalize the concepts. As indicated earlier, not much research has been done into the challenges learners experience while doing LP. Myandu (2010) is the only one who investigated challenges of learning linear programming in multilingual classrooms. Her study discovered that learners experienced challenges in formulating constraints (algebraic representation of data), graphical representation of inequalities, identification of the feasible region and maximizing a profit. Some of the reasons why the learners experienced these challenges are lack of understanding of the words in linear programming which led to the inability of learners to formulate constraints and insufficient knowledge of graphical representation of inequalities (shading) and problems with linear functions (from lower classes).

Theoretical Framework

This research is informed by Kilpatrick, J., Swafford, J., & Findell, B (2001)’s conception of Mathematical proficiency which has 5 interdependent strands. In this study I looked at only two of the strands, Conceptual understanding & Procedural fluency. (pp 118-120).

Context of the study

The study was conducted in a public school in Johannesburg central district. The LoLT of the school is English and the home languages in the school are: Southern Sotho, Sepedi, Setswana, Xhosa and Zulu. Zulu is the dominating home language. The study involved 35 Grade 11 learners. No specific criterion for choosing the class. The lessons were observed for 3 consecutive days, and 4 learners were interviewed. Total time was 4 and half hours. Observation, test & learner interviews were the instruments.

Questions in the test

1. A drink is made by mixing two juices, juice A and juice B. The total volume of the drink must not exceed 200 litres. There must be at least 40 litres of juice A, at least 50 litres of juice B and at most 160 litres of juice B. Let x be the number of litres of juice A and y be the number of litres of juice B.

   (a) Write the inequalities that represent the constraints.

   (b) Draw the feasible region.

2. A sport company makes soccer balls and netballs. It takes 8 hours to make one soccer ball and 4 hours to make 1 netball. The company can work for a maximum of 72 hours per week. Not more than 12 netballs can be made each week. The company must make at least a total of 10 balls per week. The profit on a soccer ball is R250 and the profit on netball is R100. Let x be the number of soccer balls made per week and y the number of netballs made per week.
(a) Write down the inequalities that represent the given constraints.
(b) Draw the feasible region.
(c) Find the maximum profit.

3. Find the inequalities (constraints) for each point of the feasible region below.

Analysis of results

Overview of the learner's test results

Table 1

![Bar graph showing learners' performance]
The difficulties experienced by the learners

1. The difficulty of finding and writing the constraints
2. The difficulty of plotting and identifying the feasible region
3. Difficulty of calculating the profit
4. Difficulty of translating from graphical to symbolic representation
5. The difficulty of engaging with long questions in Linear Programming

Writing the constraints include the interpretation of the words using the inequalities as was the case in questions 1(a) and 2(a). Most of these learners could not write the correct inequality signs for the words at least; at most; maximum; not more than and must not exceed. According to Kilpatrick (2001)’s strands of mathematical proficiency this difficulty has to do with the first strand, conceptual understanding.

Learner 2’s script in which she answered 1(a) and 2(a)

Learner 2: Ma’am I only remembered the implicit constraints, and Ma’am question 2 has too much reading, and so it was difficult to find the constraints.
Learner 1: I don’t know Ma’am I think the inequality sign for at least and at most still confuse me.

Questions 1(b) and 2(b) required the learners to plot the inequalities and identify the feasible region. Kilpatrick et al (2001) indicate that knowledge obtained with understanding is more powerful than knowledge memorized, because how learners represent and connect pieces of knowledge is a key factor to whether they will be able to use the knowledge acquired productively in solving problems (e.g. real life problems).

Learner 2: I did not know what to do.
Learner 3: I have problems with graphs and these inequality signs.
Learner 3: I forgot how to plot, plus I got confused. I did not remember what the teacher said we must do to the inequality signs when we plot, so I decided to draw $y = 12$ and $x = 10$.

![Figure 2](image)

Learner 3: I must identify the point on the feasible on the feasible region that will give the maximum profit and then substitute in the profit equation.

Researcher: That is right, I see you have identified the correct objective function and substituted in the co-ordinates of the points of your feasible region and your calculated maximum profit is R3700. Your steps are correct but because you were unable to plot all the constraints and identify the correct feasible region, you could not get the marks.

Learner 3: Ma’am unfortunately for me the answer depends on the previous answer. I will try harder next time.
Learner 4: I did not know what to do. I think I have a problem with the inequalities, where to use or and this whole shading thing.

Researcher: But the lines were drawn for you, all you needed to do in question 3 was to identify the straight lines and looking at the feasible region try and figure out the inequalities.

Learner 4: Yah, Ma’am it looks easy now, but I got confused while trying to do it.

Research on reading mathematical English report that while reading the learners must be able to see the relation between words, symbols and numerals (Adams, 2003).

High reading difficulty is related to word count, number of verbs and word familiarity. If the learner is not familiar with some of the words in the passage, they will have difficulty negotiating meanings of those words. (Gal, 1999 in Warren, 2006)

Learner 2: Ma’am I only remembered the implicit constraints, and Ma’am question 2 has too much reading.

Researcher: Question 1(a) and 1(b) were well done. What became a problem doing the same in doing 2(a) and 2(b)?

Learner 4: Ma’am question 2 was difficult and long, too much reading and it was difficult to write the constraints, especially the one with 8 hours and 4 hours.

Conclusions and Recommendations
Not all difficulties experienced were as a result of language. The other difficulties are
All these difficulties contribute to the learners’ difficulties in learning Linear Programming. Despite all the mediation strategies by the teacher, learners still experienced difficulties. The teacher followed Myandu’s recommendation of showing the learners the symbols. Despite her attempts to mediate knowledge, learners experienced difficulties. I recommend that teachers should make sure that learners can draw straight line graphs, can write equations of straight lines and they can represent possible solutions of linear inequalities on the number line, before starting to teach Linear Programming. Dealing with the pre-knowledge before teaching LP will definitely ensure better results in this topic. (e.g. learners should be able to draw straight lines. Must be able to determine the equation of the straight line, have the ability to determine where the possible solutions are, when given a linear inequality, and teacher should quickly find out the learners’ meaning to words like equal to, less than and more than).the strategy used by the teacher in this study be acceptable; teachers be encouraged to use long questions during teaching and learning. In this way, the learners would become used to engaging with long mathematics questions so that when they are faced with long questions in an examination situation, they would be able to deal with the language demands inherent to such questions. Since the study involved one teacher and one Grade 11 class, for 3 days. A generalization of my findings cannot be made. After teaching mathematics in Grade 11 and 12 for 13 years in multilingual classrooms of South Africa, I realise from the results of this study that I underestimated the impact a good grasp of mathematics register has on the teaching and learning of mathematics.

REFERENCES


The mathematics of water: Insights from a Grade 8 lesson episode on conservation

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The use mathematics to make sense of everyday situations that learners encounter has received increasing attention in recent years. This is especially the case in the context of the learning of mathematical literacy in South African schools. This article represents an effort to “bring into picture” the notion of using the knowledge of mathematics to uncover a critical issue of management of resources (water) and to “propose alternative ways” through which others can begin to see how instrumental mathematics can be in providing solutions that lead to sustainable use of resources, and for promoting our wellbeing. A real-life project is described in this article, and was fundamental to the orientation on curriculum being focused on here. A lesson episode, situated in the context of learning outcome 5 (Data Handling) is presented and discussed. Responses by two groups of students are presented and examined in this article to exemplify the kinds of mathematical knowledge and skills they gained and to examine how they used that knowledge to identify and elaborate on the mathematics behind the context of water conservation. The key question being addressed here is: How do middle school learners use mathematics as a tool to critically reflect on their actions?

Introduction and context
This article presents an analysis of data from a mathematics lesson episode that used an open-ended project as a tool to explore how water is managed and used. Drinking is one critical way in which water is used in the school that is the focus in this article. Close to the entrance of the school is a water tap. Learners drink directly from the tap using their own hands. The school in which the lesson was conducted is a middle school situated in a township with an average enrolment of 870 learners. The lesson was carried out with a group of Grade 8 learners. The author is a mathematics teacher in that school offering
mathematics to Grade 7, 8 and 9 learners. The lesson conducted took a form of a real life project which focused on the context of water conservation within the school, as shown in Figure 1 below.

![Figure 1: The context of the water conservation project](image)

Every day during break time (between 10h30 and 11h20) about 870 learners in the school gather and take turns around the tap to quench their thirst, drinking directly from the tap using their hands. A lot of water is lost as the learners drink directly from the tap. As an observant educator, I saw the opportunity to make my learners realise just how powerful and instrumental mathematics can be in letting learners to understand and manage available resources. From this observation a mathematics project emerged and unfolded over four weeks. Preliminary discussions about the project involved the whole classroom. I invited learners’ opinions about the context of water in the school. Learners worked in their cooperative groups to quantify the volume of water used every time during break. That is each team had to work during break time putting empty buckets under the tap so that spilled water can be collected while their fellow learners drank. Awareness of learners’ responses to open-ended tasks which involve qualitative and quantitative explanations of such occurrences would give teachers insights into how real life projects can take shape in a mathematics classroom. It would also help teachers to direct learners’ constructions of mathematical meanings in ways that encourage them to take a critical look at their actions. The qualitative analysis of data revealed several things such as learners’ preferred methods of solving problems, comments made by learners and mathematisation. The primary concern of this article is an attempt to explore different paths travelled by learners to arrive at mathematical sense-making and justifications of ideas to illustrate the learning practices that they developed. The analysis focused on classroom observations, journal entries and worksheets.

Literature

Mathematics has a special role to play in educating young people for participation in a pluralistic democratic society (Ball, Goffney & Bass, 2005:4). It is centrally about problem solving and discovery. The Programme for International Student Assessment (PISA, 2003: 32)

10The notion of “use” has dual implications is the sense that when water spills it is welcomed by the ground since it makes it wet and provides life for microorganisms. At the same time it is used by learners to quench their thirst (the purpose intended)
acknowledges that an important aspect of mathematical literacy is engagement with mathematics: using and doing mathematics in variety of situations. Changes in mathematics education emphasise learning mathematics in realistic situations, encouragement of students’ inventions, construction of solution procedures and interaction among students (Rassmusen 1997). This perspective has many similarities with the theoretical perspective of Realistic Mathematics Education (RME) developed by Freudenthal (1973, 1991). The notion of demystifying mathematics and connecting it to the experiences of learners in ways that are consistent with the demands of the outside world has been widely acknowledged (Boaler, 1998; Gutstein, 2003; Boaler, 2000). Boaler (1998:41) states that there is a growing concern among mathematics educators that students are able to learn mathematics for 11 years or more but are still unable to use this mathematics in situations outside the classroom context. Boaler uses the term “situated learning” to describe the way in which learning is linked to the situation or context in which it takes place. The context is considered relevant because it is authentic, fits learners’ experiences and is problem-centered. Projects in mathematics are encouraged to be problem-oriented. Within the context of this project, it was necessary to see how the findings of this project impacted on the school community and what kind of dispositions learners would develop after engagement in the project. Gainsburg (2008:215) confirm that secondary mathematics teachers count a wide range of practices as real-world connections. Teachers make connections frequently, but most are brief and many appear to require no action or thinking on the students’ part. In this lesson episode the context was not just about making connections. It was about raising issues relating to social and economic issues, challenging attitudes, and proposing alternative ways through which others could begin to see through mathematics and reconsider their actions.

Why the use of an open-ended project in particular? The curriculum in South African Schools, the National Curriculum Statement (NCS, Department of Education, 2003:5) calls for learners to participate fully in mathematics lessons and for teachers to identify innovative assessment practices in which the goals of the NCS can be realised. The NCS places strong emphasis on the selection of contexts in which learners can pose questions relating to human rights, social, economic, and environmental issues in their own environment (DoE, 2003:89). The use of contexts in the teaching and learning of mathematics is a pedagogic practice strongly articulated in the NCS. This is consistent with Boaler’s (1998:29) statement that mathematics must be connected to children’s reality. An open-ended project was considered appropriate given what is contained in the curriculum about using mathematical ideas to make sense of situations at Grade 8 level. The research questions addressed in this article are: (i) How can a real life project be used to raise awareness of water use and conservation in a mathematics classroom? (ii) What lessons can be learnt from such an open-ended project?

Methodology and data generation
The study was implemented through a classroom episode of Grade 8 learners participating in a mathematics real life project. This article focuses on the qualitative aspects within the study. A case study approach was adopted and an appropriate group of research participants was identified: mixed ability, Grade 8 class of 53 learners at a public school in North West Province. The project undertaken by learners was designed to raise awareness and help them develop a reflective attitude towards the use and management of water while at the same time employing mathematics knowledge. The emphasis in this paper is on the lessons learnt from the project, the impact those lessons made and the paths travelled by learners in mathematically making sense of the context. Data collection was mainly through observations, documentation of insights from learners’ written work and extracts taken from learners’ journals.
Analysis and findings

The excerpts from learners journals, calculations and examples of learners work portrayed in this discussion are all informed by the data collected by learners in their cooperative groups during break time which lasted for 40 minutes. The context that was identified for the project was not only intended to be exploratory in nature but it also provided learners with opportunities to be creative in their problem-solving techniques and to develop capacity to understand, develop and appreciate the use of mathematics. During the project period each stage was followed by whole-class discussions where various solutions offered by different groups were shared and discussed. The project titled “Make mathematics work” illuminated a sense of curiosity and motivation among learners to work. During the first stage learners engaged in the process of defining the problem, defined the objective of the project, indicated the instruments they would use to collect data and explained how they collected and analysed data. However for the purpose of this paper only the calculations performed by learners in their teams and excerpts from learners’ journals will be discussed. This project took a form of reflective practice where the teacher as a researcher was able to explore how the project contributed to her own understanding of her mathematics teaching and learning.

The following table shows data collected by groups of learners.

<table>
<thead>
<tr>
<th>Day</th>
<th>Vol. of water (litres)</th>
<th>Day</th>
<th>Vol. of water (litres)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Team A</td>
<td></td>
<td>Team B</td>
</tr>
<tr>
<td>Day 1</td>
<td>97,5</td>
<td>Day 1</td>
<td>62</td>
</tr>
<tr>
<td>Day 2</td>
<td>20,4</td>
<td>Day 2</td>
<td>45</td>
</tr>
<tr>
<td>Day 3</td>
<td>66</td>
<td>Day 3</td>
<td>37</td>
</tr>
<tr>
<td>Day 4</td>
<td>17,7</td>
<td>Day 4</td>
<td>119,300</td>
</tr>
<tr>
<td>Day 5</td>
<td>17</td>
<td>Day 5</td>
<td>125</td>
</tr>
<tr>
<td>Total</td>
<td>228,6</td>
<td>Total</td>
<td>453,900</td>
</tr>
</tbody>
</table>

What important lessons were learnt from the process of quantifying water that was used for the purpose not intended? In an attempt to respond to this question, the following extracts from learners’ journals were used. The information in Table 1 above provided some insights on what learners thought about the subject of how water is managed and used in the school. This was further confirmed by comments learners made in their journals. A written response is captured in the statement below:

L5: This project is very important we noticed lot of things like how much water is wasted every day. We also learned how to solve this problem using mathematics. I saw that mathematics doesn’t work in classroom only, we can use it in other thing like solving a problem, so I want us to continue with this project because it help us to teach other learners how to save water and how mathematics can work in other things.

The process of collecting data, i.e. collecting and quantifying water was fundamental. Theoretically, Cohen (1994:1) acknowledges that small groups offer special opportunities for active learning and substantive conversations that are essential for authentic achievement, a goal recommended in the current drive to restructure schools. The challenges experienced by
learners when working in their cooperative groups cannot be overlooked. Some comments (see L8 below) made by learners in their journals exemplified the constraints of working as a team.

L8: The problems we encountered: Some members of the group were not co-operative. Instead of coming to the tap they went for break. We are going to tell the learners in the school that water is too important in our lives so they must stop this waste. We will tell them that they must bring their own cups so that they cannot waste water.

Learners made a continuous emphasis on the notion of using mathematics to solve problems, and mathematics as something that is not only confined to a classroom context. This can be seen in comments below:

L1: From this project we learnt that we don’t only use mathematics in the classroom, we also use mathematics to solve some serious problems like waste of water in our school. We really use and need mathematics in real life.

L6: This project taught us about the importance of water and mathematics. It also taught the importance of teamwork and that mathematics is not only in the classroom, it’s all around us.

L7: In this project I realized that mathematics is not only in the classroom. We can find mathematics outside the classroom. We realized that the school pays for unused water.

A serious commitment to encouraging children to use mathematics to contribute to a solution of problems drawn from everyday lives (whether represented in texts or actually experienced in their life outside school) will also need to increase the permeability of the boundary between children’s everyday knowledge and experience, and their more purely mathematical knowledge (Cooper and Harries, 2002:21). It is notable that learners acknowledged the utility of mathematics. It was also interesting to note that learners were not much concerned about health issues related to water consumption as can be deduced from Figure 1.

In the excerpts below the first group answered the question: “What volume of water was wasted”?

Group A

---

11 The total volume of water collected during the project period 284 liters + 453,900 liters + 228,600 liters = 966,500 liters ~1KL. The Municipality charges R3.00 per 1KL. On average 1KL is lost in 2 weeks (In 4 weeks, 2KL is lost. In one month the school pays for R6.00 (2KL) for the unused/wasted water.
Figure 2: Calculations showing the volume of wasted water.

In one day approximately R0.36 is wasted.
As can be seen from above, the calculations done by Group A indicates that they went beyond the expectations of the task. Prior to the execution of the task, each team was provided with a rubric which indicated the level of competency with clear descriptions against set criteria. The rubric served as an assessment tool by the teacher. According to the criteria used, Group A’s work suggested that they exceeded the expectations because their work. Calculations accompanied by qualitative explanations as shown in Figure 2 above reflect interesting ways of solving mathematical problems. The calculations they performed show how much water will be wasted in future and the amount of money the school will continue to pay if the pattern of water use continues.

In their work as shown above there is some evidence of vigilance, ability to use data to predict the volume of water that will be wasted in future, and the amount of money that will be paid. In all their attempts they demonstrated successful attempts at vertical mathematization. In this second attempt to further explore the implication of the water waste over a 40-minute period, it appears now that they were comfortable to follow vertical mathematization, in a successful way. With these calculations they arrive to the following discovery about wasted water: In one day the volume of wasted water was 119.3 litres. In one week (5 school days) it was 596.5 litres i.e. approximately 0.6 kilolitres, and in one month it was (2386 litres = 2 kiloliters). An interesting observation is that each step during calculations was followed by a qualitative explanation to confirm their calculations. As days increase, the volume of wasted water increases. The detailed solution and calculations presented by this group raised very important questions regarding the last step of mathematisation i.e. Re-interpreting the mathematical solution to make sense of the real-life problem. For example, here the mathematical solution suggests that an amount of (R0.36) thirty-six cents is wasted per day and (R1.79) one-rand seventy nine cents is wasted per week. Does it really make sense to other learners to say that the four 25-litre buckets and two-thirds of a bucket were filled to the brim, spilled and that implied only thirty-six cents worth of water was thrown away? Is this sufficient to convince learners in a school community that they must stop drinking water this way? Importantly this raises questions about references to the realistic consideration (Cohen & Harries, 2002:9). Perhaps it could have been useful to conduct interviews to get their opinions about this. Deputy President Kgalema Motlanthe once said “It is still worrying to see a South African opening a tap of running water just to flush a grain of rice when our country is declared to be one of the countries with lack of water”.

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**Group B**

Vertical mathematization occurs when the learners’ informal strategies lead them to solve the problem using mathematical language or suitable algorithm.
Figure 4: Costs of wasted water

The calculations in Figure 4 above reflect the work that was carried by Group B. As it can be seen the volume of water which was wasted was only 66 litres. A possible explanation for the less water waste is the time frame because they collected data during a 10-minute break. Figure 4 suggests that this group took a rote approach to horizontal mathematization. Unlike Group A, their calculations are not accompanied by explanations. As it can be seen from their calculations, 6 litres of wasted water is not accounted for. In other words for this volume of wasted water (6 litres) no amount of money is wasted. This is yet another interesting observation.

Discussion
In evaluating the gains achieved by this project it was recommended that each learner take the importance of water more seriously. It was recommended that small water tanks be installed in each classroom to avoid too much traffic at the taps. Learners were encouraged to carry small bottles to the tap which they could use. The school management and the school governing body had since agreed to sponsor a sign post which is installed close to the water tap towards the school entrance. It is stated in the NCS (Doe, 2003) that contexts used in the study of mathematics need to recognize that the learner is developing moral and social identities, and accordingly, need to increasingly address issues of concern to the learner. The NCS further states that Learning Programme in the GET band is as much (if not more so) about developing sensitivity to the power of data and its possible misuse and misrepresentation as it is about learning the skills of collecting, organizing and representing data. In this project learners experienced an innovative and realistic way of developing these skills.

Concluding remarks
In social worlds where we live as ordinary human beings in multiple contexts—the family, the workplace, the school, the church, and many more, we are bound to subject our own actions and decisions to self-criticism (Mouton, 2008, p. 138). Mathematical knowledge provides a tool to human beings to inform their self-criticisms, judgments and decision on facts arrived to through computations.

It is suggested here that the teaching and learning of mathematics should not only be limited to mathematics textbooks where learners respond to questions posed by others. Contexts must be identified in which learners can pose questions, develop the competency to problem-solve, and to appreciate the usefulness of mathematics. It is through these kinds of engagements that we as mathematics teachers can assist our learners to develop competencies to solve mathematical problems that they may encounter in their daily life. For learners mathematics should be seen less as a set of disjointed facts and rules. Rather learners should view mathematics as an interesting, powerful tool that enables them to critically analyse situations in their own environment.

References

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13 Horizontal mathematization is when learners use their informal strategies to solve a mathematical problem

Uncovering meanings of a term by looking at the way it is written

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This paper provides an elaboration of my recent exploratory work (Mwakapenda, 2010) that is consistent with a project in mathematics education related to demystifying mathematics. The initial question in that work is as follows: How can one tell the meaning of a word by looking at the way that particular word is written? The discussion in this paper focuses on aspects of the word “mathematics”. Mathematics as a field is usually experienced in its written form, captured in texts of various genres at various school levels. In this paper, I propose that the way mathematics is WRITTEN (its “wrotography”, referred to here as wrotographic evidence) determines to a greater extent how it is read and spoken (verbalized). This exploratory paper has poetic dimensions (Staats, 2008) and seeks to consider various ways in which mathematics as a word can be re-written (re-presented). It explores whether and how the various ways in which “mathematics” is re-written could affect the ways in which one reads and understands the term “mathematics”. The thrust of the question being addressed is as follows: To what extent does the way the term “mathematics” is written affect the way teachers and learners read and understand mathematics? In what ways does the form in which a specific term in mathematics is written determine the way it is read and the meanings we can attach to it?

An elaboration of the nature of the argument being proposed
In documents on mathematics, the forms in which the term “mathematics” is written are often as follows: a) mathematics; b) Mathematics; (c) MATHEMATICS. Seen in this way, there are “visible” differences in which the term “mathematics” is written. In (a), the term appears in a constant lower-case lettering, while in (b), M is the only letter that is capitalized. In c), the term appears in constant upper-case lettering. The question here is: how do the ways in which the term “mathematics” is written in a, b and c affect the way in which one reads and understand the term mathematics? Does capitalizing one or more letters in the term affect the way it is read and the meanings one can attach to the term? I note here that a, b and c represent the common forms in which the term “mathematics” is written. Common ways of writing terms in mathematics are likely to lead to common ways of reading and understanding mathematics. However, I propose here that uncommon ways in which mathematics and terms in mathematics are written should lead to uncommon ways of reading and understanding mathematics. It is the uncommon forms in which mathematics and mathematical terms are written which is the focus of this paper. This exploratory paper considers some of the uncommon ways of writing the term mathematics, and the extent to which these ways of writing the term shape the way in which learners and educators read and understand mathematics. Table 1 below demonstrates this scenario.

<table>
<thead>
<tr>
<th>Common ways of writing “mathematics”</th>
<th>Uncommon ways of writing “mathematics”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics, mathematics, M</td>
<td>MATHematics, mat-HE-matics, mat-HEMatics</td>
</tr>
<tr>
<td>mathematics, MATHEMATICS,</td>
<td></td>
</tr>
<tr>
<td>MATHMATICS, Maths, e.t.c.</td>
<td></td>
</tr>
</tbody>
</table>

As can be seen in Table 1, the first column shows the term “mathematics” appearing in forms that are quite familiar (to learners and educators particularly) because these are forms in which the term often appears in school mathematics textbooks.

The form in which the term mathematics is usually written in school is largely “conventional” and lends itself to being read in traditionally common and unproblematic ways. However, it is important to consider that there is a need for teaching to attend to mathematics in unconventional approaches if we are to circumnavigate the desperate need for change in learner understandings of school mathematics. The approach that is being explored here concerns a need to examine how we write in mathematics: that if we reconsider how mathematics is written, we should provide opportunities for learners to shift the ways they see and read mathematics. For example, consider the following way in which the term “mathematics” has been re-written: mathematics → matHEmatics (mat-HE-matics). Does writing “mathematics” in the form “matHEmatics” make any difference to the term “mathematics”? If so, what is the difference? And how does that difference shape the way we make sense of the term “mathematics”? What is the significance of writing mathematics in the “newer” version: “matHEmatics”? What is the significance of the term “HE” in the term “matHEmatics”? What comes to mind when our attention is drawn to the term “HE”?

What is being proposed in this paper is an approach to writing that provides opportunities for learners and educators to see mathematics in newer, fresher and less common ways. It is suggested here that the term “HE” in “matHEmatics” should be able to draw the reader to an
important association or connection of mathematics with people: HE and THEM (see in Table 1). What makes it possible to see mathematics in this connected way stems from the way the term has been re-written. This paper is also a demonstration of the tools of language-in-use and linguistic play that is intended to reveal some of the connections that can be explored by considering the term “mathematics”.

Initial empirical evidence

Consider again the thrust of the question being addressed in this paper: To what extent does the way the term “mathematics” is written affect the way teachers and learners read and understand mathematics? In what ways does the form in which a specific term in mathematics is written determine the way it is read and the meanings we can attach to it?

In this section, I present initial data collected from a small group of pre-service student-teachers (n=19) in order to obtain insights about the meanings they attach to the way the term mathematics is written. The students were given a questionnaire, shown in Figure 1 below concerning the way the term “mathematics” is written”, as follows:

This questionnaire is about the way the term “mathematics” is written. It is about exploring other ways of writing the term, and noticing what comes to mind when the term is written in other ways. For example, one can write the term “mathematics” as “ma-THEM-atics”. In this other way of writing, one can see another term “THEM” inside the term “mathematics”. With this in mind, answer the following questions as fully as possible.

1. What comes to your mind when the term is written as: “ma-THEM-atics”?
2. When you write the term as mat-HE-mat-ics, what does this make you think of?
3. What about when you write the term as “math-EMA-tics, what comes to your mind?
4. Think about another way of writing the term “mathematics”, and say what that way of writing can make someone think about.
5. Now think about another way of writing the term “function”, and say what that way can make someone to think about.
6. Now, according to your own understanding, what is mathematics?

Figure 1: Questionnaire on “the way the term ‘mathematics’ is written.”

In this paper, I reflect on students’ responses to items 2 and 3 of the questionnaire. This reflection is intended to reveal some of the ways in which the students associated the terms “HE” and “EMA” emerging from a rewriting of the term “mathematics”.

With respect to item 2, it was expected that most students would associate the term “HE” with people, specifically the “male” gender in mathematics. The following table shows students’ responses to this item.

<table>
<thead>
<tr>
<th>Students’ thoughts about the “HE” component of “matHEmatics”</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1: “It makes me to think that the word HE is referred to the man who teaches mathematics (lecturer)”</td>
</tr>
<tr>
<td>S2: “The HE makes me think of a gender”</td>
</tr>
<tr>
<td>S3: “HE, too is concerned with the unreasonable effectiveness of mathematics the Natural Sciences”</td>
</tr>
<tr>
<td>S4: “I think about a man. It try to refers that Mathematics was created by a man. and I think about a Help meaning that mathematics can assist to solve problems”</td>
</tr>
<tr>
<td>S7: “Humans are all welcome in Education”</td>
</tr>
<tr>
<td>S8: “High intension lead[s] to effective learning…”</td>
</tr>
<tr>
<td>S9: “It makes me think of, you must be able to think like a man. have some explanation”</td>
</tr>
<tr>
<td>S10: “Maths is for males”.</td>
</tr>
</tbody>
</table>
S14: “I think about HECTOPASCALS (hpa)”
S17: “… In my second thought I can say HE can be the abbreviation of Help Everyone (HE) in
thinking wisely and be the best in solving problems”

As can be seen from Table 2 above, students associated the term “HE” to the personal/human
dimension of mathematics and mathematics education. “HE” is associated with “the man”,
“the man as creator of Mathematics”. S10’s comment: “Maths is for males”, summarises the
stereotypical tendencies associated with participation in mathematics in which males are
thought to have a superior ability. Some students, e.g. S7, S8 and S17 associated HE with
abbreviations. However, the majority of responses to item 2 suggest that it is important to
consider mathematics as a human activity. This is consistent with current thinking in
mathematics education and mathematics curricula globally. S14’s response: “I think about
HECTOPASCALS (hPa)” is interesting. This is because it reveals an important connection
of mathematics and the discipline of physics. The pascal is the SI derived unit of pressure
named after Blaise Pascal, the French mathematician, physicist, inventor, writer and Catholic
philosopher. It is a measure of force per unit area. One hectopascal corresponds to
approximately 0.1% of atmospheric pressure (near sea level).

With respect to the term “EMA”, one would also have associated it with the human dimension
of mathematics. However, the way in which students responded to item 3 was contrary to this
expectation. This can be seen in Table 3 below.

**Table 3: Students’ thoughts about the “EMA” component of “mathematics”**

<table>
<thead>
<tr>
<th>Student</th>
<th>Thought</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>“This makes me to think that the word EMA stands for Education for Mathematics Authority”</td>
</tr>
<tr>
<td>S2</td>
<td>“EMA” makes me think of Exploring Mathematics and also Applying it on real life situation.</td>
</tr>
<tr>
<td>S4</td>
<td>“EMARGINATION of numbers, because in Mathematics we have something like emarginary roots”</td>
</tr>
<tr>
<td>S5</td>
<td>“Combination of things or variables to make a problem solved”</td>
</tr>
<tr>
<td>S7</td>
<td>“Effective Methods may be Admirable”</td>
</tr>
<tr>
<td>S8</td>
<td>“Essential Measurements lead to the Action”</td>
</tr>
<tr>
<td>S9</td>
<td>“What comes to my mind is thinking of the Multiplication and Addition together as evaluating problem that you come across”</td>
</tr>
<tr>
<td>S10</td>
<td>“Maths is not for me but EMA”</td>
</tr>
<tr>
<td>S11</td>
<td>I think the word “EMA” is a shortcut for something… e.g. “E” ARN “MA” THEMATICS MEANS TO GAIN IT</td>
</tr>
<tr>
<td>S12</td>
<td>“EMA is the name of the female and it is a Shangan[o]s name”</td>
</tr>
<tr>
<td>S13</td>
<td>It makes me think that when you are doing mathematics you have to manage yourself and also give yourself enough time when practicing it because it is time consuming”</td>
</tr>
<tr>
<td>S14</td>
<td>EMA can mean Estimate Manipulate and Attempt questions or problems</td>
</tr>
<tr>
<td>S16</td>
<td>It means that [mathematics] also is for ladies, since the name EMA is associated with ladies.</td>
</tr>
<tr>
<td>S18</td>
<td>E = Energy M = motivational A = attractive. Maths is attractive and when having energy you’ll be motivated on it</td>
</tr>
</tbody>
</table>

Most of the students associated EMA with non-human aspects: abbreviation, things, processes
and methods. For example, S7 associated EMA as an acronym for “Effective Methods may be Admirable”. One needs to ask the question: why did only a few students (3: S10, S12 &
S16) associate the term “EMA” with the human aspect of mathematics? S10, the only female
student who associated EMA with the human dimension of mathematics, said: “Maths is not
for me but EMA”. Could it be that most of the students responded this way because they considered mathematics as a “male” subject? Is it possible that students could not associate “EMA” (traditionally a name for females) with mathematics because they have not seen many EMA’s participating in mathematics? Is it because they expect HE’s and not SHE’s? This is a key question that needs following up empirically.

A possible reason why there appears to be limited presence of the human dimension in students’ responses to item 3 (EMA) is education background. The way students may have been taught mathematics up to this level is unlikely to have considered human ways of thinking and being in mathematics. This can be deduced from one of the students’ responses, S7, who said:

In mathematics, we don’t use any methods to teach. e.g. you cannot use [a] narrative methods because learners will not be able to understand. The methods that must be used can be problem solving methods so they can be able to solve problems in their own way and understanding.

This suggests that at first-year university, most students will not have been exposed to humanistic (including narrative) ways of thinking and working in mathematics. Engaging students in this reflective activity involving the term mathematics has therefore been useful in the sense that it has attempted to reveal students’ perceptions of behaving and participation in mathematics. However, for some students, it might be the case that this activity enabled them to see “mathematics” in newer ways. In this way, this activity can be seen to be contributing towards demystifying mathematics so that it can be seen as a human activity in line with recent claims and goals of school mathematics.

Conclusion
In addition to conducting a further analysis of students’ responses to items 1 to 6 in the questionnaire, we need to ask a broader question about how this way of thinking (re-writing mathematics) connects to the broader domain of the activity of mathematics education. I argue that this paper is a demonstration of a grounded approach towards understanding mathematics. This approach is essentially about seeing. It is about seeing of the following forms: (1) Seeing the mathematical in the non-mathematical, and (2) Seeing the non-mathematical in the mathematical, in order to give a place for the non-mathematical in mathematics. This approach is about breaking taken-for-granted boundaries between mathematical and non-mathematical domains. In this paper, I demonstrate a process which I call un-earthing (un-ear-thing) mathematics in such a way that it enables one to hear (h-ear) voices that mathematics speaks (sPEAKs) when it stands face-down on its pillars. The process I present here is poetic and neo-aphoristic (Knijnik & Bocasanta, 2010). It begins with a look at mathematics as a term (a thing) that lends itself to be heard when it is broken down, and exposed in-side-out. This approach is about unearthing (un-ear-thing!) the pillars of mathematics. It looks at elements that “hem” or “tie” mathematics together, e.g. people (HE and EMA) as demonstrated in the above analysis of students’ responses.

References
The use of language in the Learning of Geometry

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Introduction
This study is essentially concerned about the use of language in the learning and problem solving in Geometry. The research draws upon the theories provided by Van Hiele’s Model of Thinking in Geometry, Piaget’s Child Conception of Geometric Space, Gagne’s Hierarchies of Learning and Vygotsky’s Zone of Proximal Development.

The field work was completed through a study of eight Secondary Schools and hundred and five learners. Seventy five learners were selected from Grade 9 classes and thirty from grade 10. All eight schools were selected using simple random sampling from Kwa-Zulu Natal Department of Education.

The instruments for the collection of data were formulated through the following:

- Questionnaires for the learners.
- Tasks performed by individual learners.
- Tasks performed by learners in groups of five per school recorded.

The Research Questions

- Are the learners able to break the diagrammatic information down into geometric statements, axioms and theorems?
- Have learners in grade 8 and 9 accumulated sufficient concepts and language which can enable them to make connections between axioms, geometric statements and theorems.
- Do learners use routine methods or display knowledge and mathematical understanding in their process of solving a given task?

Literature Review

Concept and concept Formation

According to Cooney (1977), a student’s ability to learn mathematics is directly related to his or her understanding of mathematical concepts and principles. He further argues that, experienced teachers know that concepts are basic building blocks of thinking, particularly higher level thinking in mathematics. Knowing the definition of a concept is important, since students will need to communicate about the concept and eventually be able to interpret it. (Toumasis, 1995:98)
A similar statement is cited by Cooney et al. (1975) “Communication breaks down when people do not have certain concepts.” (p.90)

**Language**

Hugo (1991:32) says that when pupils read (mathematics) geometry, they use some of their reading skills, namely;

a) following instructions.

b) problem solving.

c) The ability to read deductively

d) Reading speed and

e) The ability to determine the relevant and irrelevant information.

She further says “mastering these skills means mastering the language used which in turn depends heavily on mastery of concepts within the context.” (p.32)

Pimm (1987) asserts that general notion of communicative competence involves knowing how to use language appropriately to context. This is in agreement with Barnard (1990) who states that mathematics is a language in its own right.

In Wiskunde is daar Komplekse verbandhoudende Reëls. Die bemeestering van `n wiskunde woordeskat is indirek `n bemeestering van hierdie reëls en die gevolglike bemeestering van begrippe om Wiskunde te verstaan. Hierdie wiskundige woordeskat maak deel uit van die onderrigtaal van wiskunde, dit is die wyse, waarop oordrag van kennis plaasvind.

(Barnard, 1990:87).

Barnard means that in mathematics there is a complex connectedness of rules. He further states that the mastery of mathematics vocabulary is indirectly the mastery of these rules which is followed by mathematics comprehension and understanding. (As translated by author) He further asserts that a student who does not understand mathematical language does not easily cope with mathematical instruction.

**Theoretical Framework**

This study draws upon five theories namely, Van Hiele’s Model of Thinking in Geometry, Piaget’s Cognitive Development Stages, Piaget’s Child Conception of Geometric Space, Gagne’s Hierarchies of Learning and Vygotsky’s Zone of Proximal Development.

According to Van Hiele as quoted by Hoffer (1981),

Learning is a discontinuous process. That is, there are “jumps” in the learning curve which reveal the presence of discreet, qualitatively different levels of thinking. The levels are sequential and hierarchical.

Therefore for students to function adequately at one of the advanced levels in the Van Hiele hierarchy, they must have mastered large portion of lower levels.

Piaget and Inhelder (1969) asserts that the child’s developmental processes are slow, but continuous and characterised by distinct stages and sub-stages. The stages are each underlined by different patterns of behaviour.

Vygotsky supports the group work when he states that learners work better when they perform in collaboration with more capable peers. Vygotsky determines two developmental levels that must be considered in order to discover the actual relations of
the developmental process to the child’s learning capabilities namely, the actual
developmental level and the potential developmental level. Vygotsky (1934/1978)
called this difference between these two developmental levels, the zone of proximal
development.

The zone of proximal development is the distance between the actual
development as determined by independent problem solving and the level
of potential development as determined through problem solving under
the adult guidance or in collaboration with capable peers. (p86)

Vygotsky’s statement is supported by Gagne (1977) who states that learners need
certain basic background knowledge before they are capable of performing or
understanding certain tasks. He further says:

capability with which the pyramid can be started in “problem solving”,
the learner must first know principles. In order to understand certain
principles, he/she must know specific concepts and prerequisites for
concept are particular associations or facts. With this chain of knowledge
the learner might be able to perform the task given.

Instruments

In order to answer the research questions, questionnaires, individual tasks and group tasks
were used. Among the tasks given to learners, for the sake of this presentation one example
will be discussed below. The overall results will however be stated in this presentation.

Task

Study the figure below careful.

- Write down any information given in the diagram.
- Find the values of: \( \hat{a} \) and \( \hat{b} \)

This task required learners to apply the elementary theorems, namely:
(a) The sum of the adjacent angles on a straight line equals 180°. Or Adjacent angles on a
straight line are supplementary
(b) The sum of the interior angles of a triangle equals 180°. Or Interior angles of a triangle
are supplementary.
(c) An exterior equals the sum of the two opposite interior angles.

Some of expected responses were as follows:
- HEFG is a straight line
• \( \hat{a} \) and \( \hat{b} \) are the adjacent on a straight line
• \( \hat{D} \) is 32°.
• \( \measuredangle HED \) is 111°
• 111° is an exterior angle of \( \triangle DEF \).
• \( \hat{b} \) is an exterior angle of \( \triangle DEF \).
• \( \hat{a} + 32° = 111° \)

Suggested Solution

<table>
<thead>
<tr>
<th><strong>METHOD 1</strong></th>
<th><strong>METHOD 2</strong></th>
<th><strong>STEP</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>( 111° + \measuredangle DEF = 180° ) ( \quad ) ( \text{adjacent angles on a straight line.} )</td>
<td>( \hat{a} + 32° = 111° ) ( \text{sum of two opposite interior angles of a } \triangle )</td>
<td>( A )</td>
</tr>
<tr>
<td>Then ( \measuredangle DEF = 180° - 111° = 69° )</td>
<td>Then ( \hat{a} = 111° - 32° )</td>
<td>( \therefore \hat{a} = 79° )</td>
</tr>
<tr>
<td>( \therefore \measuredangle DEF = 69° )</td>
<td>( \therefore \hat{a} = 79° )</td>
<td></td>
</tr>
<tr>
<td>( \hat{a} + 32° + 69° = 180° ) ( \text{sum of the interior angles of a } \triangle )</td>
<td>( \hat{a} + 32° + \measuredangle DEF = 180° ) ( \text{sum of the interior angles of a } \triangle )</td>
<td>( B )</td>
</tr>
<tr>
<td>Then ( \hat{a} = 180° - 101° ) ( \text{=} 79° )</td>
<td>Then ( 79° + 32° + \measuredangle DEF = 180° )</td>
<td>( \Rightarrow \measuredangle DEF = 180° - (79° + 32°) )</td>
</tr>
<tr>
<td>( \therefore \hat{a} = 79° )</td>
<td>( = 180° - 111° )</td>
<td>( = 69° )</td>
</tr>
<tr>
<td>( \therefore \measuredangle DEF = 69° )</td>
<td>( \therefore \measuredangle DEF = 69° )</td>
<td></td>
</tr>
<tr>
<td>( \hat{a} + \hat{b} = 180° ) ( \text{adjacent angles on a straight line} )</td>
<td>( \hat{b} = 32° + \measuredangle DEF ) ( \text{an exterior angle equals sum of two opposite interior angles} )</td>
<td>( C )</td>
</tr>
<tr>
<td>Then ( 79° + \hat{b} = 180° )</td>
<td>Then ( \hat{b} = 32° + 69° )</td>
<td>( \Rightarrow \hat{b} = 32° + 69° )</td>
</tr>
<tr>
<td>( \Rightarrow \hat{b} = 180° - 79° = 101° )</td>
<td>( \therefore \hat{b} = 101° )</td>
<td>( \therefore \hat{b} = 101° )</td>
</tr>
</tbody>
</table>
Results

The table below shows how the groups performed in trying to find the values of $a$ and $b$.

<table>
<thead>
<tr>
<th>Group Code</th>
<th>Mathematical steps mastered</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>IG01</td>
<td>*</td>
</tr>
<tr>
<td>IG02</td>
<td>*</td>
</tr>
<tr>
<td>KG03</td>
<td>*</td>
</tr>
<tr>
<td>KG04</td>
<td>1</td>
</tr>
<tr>
<td>NG05</td>
<td>1</td>
</tr>
<tr>
<td>NG06</td>
<td>1*</td>
</tr>
</tbody>
</table>

Key:
The star(*) shows that learners could not master the step whilst “1” represents the step which was mastered. 1* shows that the step was covered but not convincing. This however, led to the mastery of the steps which followed.

• The groups IG01, IG02 and KG03 could not even make a start. Learners could not give the information as reflected by the diagram.
• Group NG05 did not follow instruction, i.e. writing the information as reflected by the diagram.
• They managed step 1 of method 1 and could not do anything further.
• Group NG06 manage step 1 of method 1, but could not give reason in a proper way. They said $111^\circ$ and $\triangle DEF$ are angles on the straight line.
• Group KG04 managed all steps following method 2. They had only two steps since after getting $\hat{a}$, they used $\hat{a}$ and $\hat{b}$ as adjacent angles on the straight line then solved for $\hat{b}$.

General observation

• The groups had a difficulty in making any move. There was a lack of skill of interpreting diagrams.
• Some groups wanted to solve for $\hat{a}$ and $\hat{b}$ simultaneously.
• One of the groups stated that $\hat{b} = 32^\circ$ with the reason that they were alternating.
• Some groups claimed that $\hat{a} = 111^\circ$ with the reason that these were corresponding angles.
• Groups concentrated on getting the values of $\hat{a}$ and $\hat{b}$ rather than looking for the data then formulate logical statements based on the data towards solving the problem.

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Analyzing Socio-cultural Values Influencing the Development of Mathematics Teaching Skills of UNISA ODL Pre-service Teachers

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Abstract
The purpose of this study was to document the social and cultural values that influence the development of mathematics learner-centered teaching skills of Open and Distance Learning (ODL) pre-service teachers. With lack of face-to-face tuition that is prevalent in formal teacher education programs ODL pre-service teachers lack models of exemplary practices to inform their practice. Preliminary results from archival documents, e-mail correspondence and telephonic interviews reveal that passiveness of children to adults' ideas which is a traditional African way of children's respect for adults filtered in the mathematics classrooms of the pre-service teachers. Some school ethos of restricted learner noise during lessons limited the use of cooperative learning.

Key words: Socio-cultural values, Learner–centered; ODL

Purpose of the study
Learning mathematics is a social activity in which a community of learners can engage in exploring and searching for patterns and relationships to determine the nature and principles connecting variables in their natural phenomena (Schoenfeld, 1992). Thus the effective
teaching of mathematics is influenced by a multitude of factors in which teachers play important roles in the instructional process. Effective teaching of mathematics is a complex activity that is influenced by a teacher’s social and cultural beliefs, experience, content knowledge, awareness of classroom environments that can encourage learner active participation; challenging and extending learners’ thinking capacities (Lehtinen, 2004; Turnuklu & Yesildere, 2007). Collay (2006) also noted that teachers’ values influence their teaching practices. Teachers’ values, knowledge and judgments influence the decisions that they make which in turn determine their plans and actions during instruction (Fennema & Frankle, 1992). Teacher knowledge for teaching mathematics, teacher beliefs and the impact of reform-based practices (Thompson, 1992) has received attention in the literature. There is paucity of literature on the development of teaching values of teachers (McClintock, O’Brien & Jiang, 2005) particularly the social and cultural values that influence pre-service teachers studying through Open and Distance Learning (ODL) mode. Pre-service teachers in formal teacher education programs can learn pedagogical theories from a socio-cultural perspective during organized activities in which inquiry and negotiation of meanings with peers are central to understanding (Jaworski, 2005) unlike their counterparts in ODL settings. In ODL pre-service teachers can study at their pace, choice of time and place but go for school attachment during a common period. The extent to which the social and cultural values that influence ODL pre-service teachers to base their practicum teaching on constructivist scientific theories has not been explored. The present study attempts to contribute literature to reduce this gap by seeking answers to the research question: What are the social and cultural values that influence the development of mathematics learner-centered teaching skills of ODL pre-service teachers enrolled at the University of South Africa (UNISA)? Answers to this research question may provide insight into the debate on how pre-service teachers develop their teaching identities.

Theoretical framework

Thompson (1992) showed that there was ample evidence that teacher beliefs influence their instructional decisions. Beliefs are the convictions that teachers hold to be true without proof. For instance, teachers with traditional teaching beliefs take school mathematics as an endless sequence of truths to be memorized by learners and teaching them effectively involves transmission of concepts and procedures which learners are supposed to regurgitate and reproduce when asked (Battista, 1999). On the other hand, teachers holding learner-centered views believe that mathematical knowledge is tentative and generative, that the tools of
mathematics are abstraction, symbolic representation and manipulation (Schoenfeld, 1992). For such teachers, doing mathematics is enculturation of learners into the development of positive attitudes, personal interest, perseverance and habits of the mind that can lead into gaining mathematical understanding. Teacher beliefs are originally shaped by their social and cultural values during socialization in society and later by the education that they receive. For instance, instructional beliefs are shaped by the methods that teachers used to master mathematical concepts and the teaching methods used on them during their school days. Turnukulu and Yesildere (2007) noted that Pedagogics instructors positively influence pre-service teachers’ beliefs if they model the teaching practices that they encourage them to enact in their practicum teaching. Theoretical presentation of learner-centered methods in the study guides of ODL pre-service teachers without instructor modeling of how to enact them may not be effective in reducing the research-practice gap of the effectiveness of these learning approaches. Given the ODL pre-service teacher lack of models of how to enact learner-centered methods during teacher education, the overarching goal of the present study is to document the social and cultural values that influence them to build up their own pedagogical skills during practicum teaching using the fragmented learner-centered learning strategies theoretically presented to them in the methods study guides.

**Context of the study**

UNISA offers undergraduate and post graduate studies to both South African and international students through the ODL mode. For the purposes of this study only the Bachelor of Education (B.Ed) pre-service teachers training to teach mathematics to grades 4 – 9 are considered. Persons with Grade 12 pass who are gainfully employed or otherwise meet the selection criteria can study this B.Ed program over a period of four years. Students on this program study a minor and a major subject as well as an additional indigenous language in order to make progress toward promoting equity among all learners (Fiske & Ladd 2005). Eleven indigenous languages characterize the South African rainbow nation in which English is the official medium of instruction. Teacher code-switching during instruction between English and any two indigenous languages is a strategy used to improve fairness and development of a state of impartiality of all learners irrespective of their gender, race, religion and disability by providing equal access to a high-quality instruction and the services that all learners may need in order to benefit from the education system.

UNISA pre-service teachers engage in school attachment of 25 weeks during the four years of the B.Ed program. The integration of theory and practice throughout the four years of the
program is assumed to enhance pre-service teachers to understand the nature of theory and the contexts it is supposed to be applied. During the period of school attachment, the pre-service teachers are attached to mentor teachers based at the same school. The number of pre-service teachers on school attachment during any given semester in addition to the geographical locations of the attachment schools makes it impossible to train mentor teachers to offer uniform coaching to the pre-service teachers. Assessment of the classroom practices of the pre-service teachers are made by district assessors, themselves specialists in the subjects they assess, who are appointed by the university. The district assessors make assessment reports on a uniform template that act as a standardizing instrument which is accepted as proxy of university lecturers’ assessments.

Sources of data

Data for this study were archival documents on the pre-service teachers’ classroom assessments, e-mail communication and telephonic interviews. A preliminary analysis of 56 pre-service teachers from different year groups of their B.Ed studies is used to answer the research question posed for this study. The three data sources are assumed to triangulate the emerging issues from the study. The way the pre-service teachers addressed the fundamental aspects of learner-centered classroom environments such as cooperative learning, posing questions for scaffolding learners and rooting their instructional practices in the “educational paradigms in the African socio-cultural and epistemological frameworks’ (Higgs & van Wyk, 2007: 179) depicted the social and cultural values that influence their development of learner-centered teaching skills.

Results and discussion

Pseudonyms of pre-service teachers whose responses are used as intercepts are to protect their identities. In a lesson on ratios to a grade 7 class Michelle asked learners to reduce the ratio 2 ¼: 9 to its lowest term. Learners solved the problem in groups. Any two of them wrote the following two solutions on the board:

1: 2 ¼ ÷2 ¼; 9 ÷2 ¼ = 1: 4; 2: 2 ¼ ÷ 9; 9 ÷ 9 = ¼: 1

Michelle was conscious of the fact that mathematical problems have one correct answer but was not sure which of the two solutions was correct. She was not conceptually aware of the procedures of “convert and multiply when dividing by a fraction” in solution 1. This claim
was evident in the explanation “when you divide a number by itself the result is 1. So $2 \frac{1}{4} \div 2 \frac{1}{4}$ is 1; $9 \div 2 \frac{1}{4} = 9 \div \frac{9}{4} = \frac{1}{4}$.” (Michelle, June, 2010). She could not explain why her result from this working ended up as $2 \frac{1}{4} \div 2 \frac{1}{4}; 9 \div 2 \frac{1}{4} = 1: 4$. Michelle did not probe the learners who presented the solutions on the board the procedures they used neither did she ask other learners to assess the solution strategy. For her an answer is either correct or wrong and which of the two solutions was correct was her dilemma.

Michelle approach mathematics teaching from a conservative use of learner-centered methods. Whilst she acknowledges the usefulness of these methods, she does not nurture the full potential of the methods to develop learner diligence, curiosity, systematic and inventive methods by allowing them to discuss their solution strategies or asking other learners to explain the logic of solutions presented on the board. Lack of nurturing these skills can limit learner use of their initiatives and imaginations as they concentrate on the execution of procedures (Schoenfeld, 1992).

In another lesson Michael was teaching areas of circles to a Grade 8 class. The area formula was written on the board $\pi r^2$ and demonstrated how to use the formula to calculate the area of a circle with radius $3 \frac{1}{2}$ cm. Learners were given five radii dimensions and asked to find the areas of the circles individually. During the post-lesson reflection Michael argued that group work could have been used but there were some problems of using it with this class. He argued that:

The learners can be too noisy during group activities that classroom management will be impossible to maintain. Also in a lesson of 30 minutes there is hardly time for group work to engage in discussions and negotiate solution strategies (Michael May, 2010).

Michael believes in the social construction of mathematical concepts through the use of group work but cannot use them because of time constraints, classroom management problems and discouragement by the mentor. The school ethos limits Michael’s implementation of learner-centered methods to demonstrations of mathematical algorithms to learners who are expected to accept and use them. The view of learner passive recipient of information is rooted in indigenous African tradition where it is a taboo for children to doubt adults’ decisions.
Equipped with the cultural belief that learners believe that adults are always right and his school days during the apartheid era, Michael believes that students can learn passively. During apartheid era critical thinking was not encouraged among black learners because learners were to be subservient to authority and “locked into ways of thinking that worked to oppress them” (Higgs & van Wyk, 2007: 183).

Conclusion

With lack of face-to-face tuition that is prevalent in formal teacher education programs ODL pre-service teachers lack models of exemplary practices to inform their practice. Preliminary results reveal that passiveness of children to adults’ ideas which is a traditional African way of children’s respect for adults filtered in the mathematics classrooms of the pre-service teachers. Some school ethos of restricted learner noise during lessons limited the use of cooperative learning.

The preliminary analysis of the data sources, revealed the social and cultural values that influence ODL pre-service teachers. A complete analysis of the data would provide a better understanding of how socio-cultural values impact the development of mathematics teaching skills of UNISA ODL pre-service teachers. The research is ongoing. It is recommended that further research focus on how to provide models of exemplary practice for ODL pre-service teachers.

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The perceived impact of an ACE Mathematics professional development programme

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The focus of this paper was to seek answers and to critically engage with questionnaires administered to three groups of final year ACE Mathematics teachers, who have completed a professional development course over two-years of part time study. Semi-structured interviews using a random sample of teachers were used to interrogate what impact the course has had on their mathematical teaching ability. One ‘strand’ in the offering of the ACE, is a strong emphasis with a focus on supporting teachers in the classroom and their practice. Research has shown that the focus on professional development and growth should be about the personal and professional identity of the whole teacher so that they are able to improve student learning. The RUMEP course subscribes to this idea of providing quality support and mentoring to teachers on the course and to enable them to reflect on teaching and learning individually and with colleagues.

Findings indicate that teachers feel very strongly that they have been equipped to deal with a multitude of mathematical aspects as regards classroom teaching from content knowledge, pedagogy, reflection on own teaching and alternative assessment strategies.

Introduction

Professional development for teacher education in South Africa has over the last decade taken on many different guises, both good and bad. The body responsible for Continuing Professional Teacher Development (CPTD) is the South African Council for Educators (SACE). It is necessary for this body to recognise the ‘needs’ of teachers and provide accredited courses for them. The closure of colleges of education has had a noticeable influence on the number of teachers trained. With an educational crisis that has seen shocking midyear exam results in all provinces in 2010, the government has announced several changes to the curriculum. The curriculum will no longer be conceived in terms of learning outcomes and assessment standards but will provide details of what teachers must teach and assess. The amended National Curriculum Statement Grades R -12: Curriculum and Assessment Policy Statement (January 2011) replaces the National Curriculum Statement Grades R-9 (2002) and the National Curriculum Statement Grades 10-12 (2004) and aims to give teachers more time for teaching and less time being spent on administrative issues and project work done by
Rhodes University Mathematics Education Project, a non-governmental organisation attached to Rhodes University has over the last fifteen years been involved in the professional development and the upgrading of teacher qualifications in mathematics. A major aim of the project is to improve the quality of mathematics education at both primary and secondary level. One ‘strand’ in the offering of the ACE, is a strong emphasis with a focus on supporting teachers in the classroom and their practice. A large proportion of those teachers who have received training at the university have moved into promotion posts in schools and curriculum and subject advisor posts in the Department of Education. With this in mind, this short paper looks at the evaluation of the ACE Mathematics course and its impact on teaching.

Theoretical Framework

There is no doubt that the need for high quality professional development courses for teachers is necessary. Very few research studies have explored the relationship between professional development and teachers and student learning (Garet, Porter, Desimore, Birman & Yoon 2001). At RUMEP, we believe that the interplay between the curriculum in helping teachers to teach successfully and their students’ performance is crucial to its success.

(Guskey, as cited in Moletsane, 2004, p. 201) defines professional development “as those processes and activities aimed at enhancing the professional knowledge, skills and attitudes of educators so that they are able to improve students’ learning.” He argues that professional development must for all intent and purposes have absolutely clear, attainable goals which must be on-going, with systems in place for monitoring and support. This implies that the focus on professional growth and development should be on the personal and professional identity of the whole teacher (Hargreaves, 2003). The RUMEP course subscribes to this idea and believes in providing quality support and mentoring in the form of classroom visits and co-teaching to bolster the teachers’ self-esteem. In total agreement with (Day, as cited in Moletsane, 2004, p. 202) who states “that professional development programmes should build rather than destroy the self-esteem and self-efficacy of a profession which ... needs informed caring, support, rather than criticism.” Clarke & Hollingsworth (2002, p. 947) argue that “if we are to facilitate the professional development of teachers, we must understand the process by which teachers grow professionally and the conditions that support and promote that growth.”

The Professional Standards for Teaching Mathematics (NCTM, 1991, p 168) state categorically that a primary factor in teachers’ professional growth is the extent to which they “reflect on learning and teaching individually and with colleagues.” Regarding reflection, the teaching portfolio in the RUMEP programme is used as both a tool to promote professional development and as an evaluation of the learning of students. In particular, what is of importance here is that students are engaged in self-improvement and this allows the teacher the opportunity to show a much greater depth of understanding of what is happening in the mathematics classroom (Spanneberg & Penlington, 2006).
Research design and methodology

This small scale study is described as qualitative in nature and lies in the interpretive paradigm as it is interested in individuals (Cohen & Manion, 1994). It looks to understand phenomena and to interpret these in a natural setting (Cantrell, 1993).

The study uses the phenomenographic research approach conceptualised by Ference Marton (1981) to find out in a qualitative form, the various ways people experience, perceive, interpret and understand aspects of a phenomena in the world at large (or a certain aspect of reality). Not all people experience a given phenomenon in the same way. This empirical research approach argues that although the results of this study are useful, they do not profess to signify the truth. It does however make assumptions about the nature of conceptions. The central assumption is that “conceptions are the product of an interaction between humans and their experiences with the external world.” (Svensson, 1997:166). These conceptions are derived from people thinking about their external world through language. In this research, the researcher is studying the awareness and conceptions of the subjects being studied (Marton, 1994).

In phenomenographic research, it has been purportedly reported that each phenomenon or principle can be conceived in a finite number of qualitatively alternative ways (Marton, 1994). Categories of description of the various conceptions are analysed by identifying the conceptions and looking for their underlying meanings and the relationship between them (Entwistle, 1997). The set of ordered and related categories of description are called the outcomes space of the concept that is being studied (Marton, 1994).

The main sources of data collection are questionnaires and interviews. A questionnaire as a tool was used in this study, as it is an easy way of gathering information from teachers by asking questions where the questions can be classified as being both open or closed (Gillham, 2000). Questionnaires covering three years of final year students (n=100) were categorised to look at similar themes. By using a questionnaire and asking open questions, gave each teacher the opportunity to express their views or ideas.

The purpose of the interview was to get each participant to examine, describe and reflect on his or her experiences and then recount these experiences to the researcher to arrive at some common understanding (Booth, 1997). Categories were identified and drawn up and a description of the ways in which different people experience a concept were analysed. Multiple aspects of a given phenomenon and differences and similarities were studied in an attempt to develop an outcome space for each aspect.

Discussion of the findings

The findings have been grouped into two main categories or phenomena namely, Category 1: positive aspects of the course and Category 2: negative aspects of the course. These two categories have further been subdivided into three subcategories namely, Mathematics Content, Mathematics Education and Other. A third component namely, attitudes and beliefs will not be discussed.
Category 1: Positive aspects of the course

Mathematics Content

Regarding the positive aspects of the mathematics content taught mentioned by the teachers, there was an overwhelmingly majority who were confident of teaching all the learning outcomes including problem solving and different solution strategies to children especially when solving word problems using the four basic operations. Teachers mentioned that topics which they had experienced difficulty had been adequately dealt with and that conceptual understanding of mathematics concepts was also strongly emphasized. The use of simple readily available resource material and the RUMEP resource material supplied to teachers ensured that teachers understood the mathematics. The materials used were found to be useful especially the fraction circle material, the different number sense grids and the Cartesian plane used to teach transformational geometry. The materials made the work easier to understand and more enjoyable to the learners. The materials brought into the classroom an atmosphere of discussion.

Teachers responded that the course had been taught in a positive, constructive manner which had helped many to grow professionally; it had taught them to think about the maths being taught which had developed their interest in the subject. A number of teachers indicated that
the course had empowered them and that other teachers respected them for their expertise. The information imparted to them had been invaluable as a high standard had been set, with the course being school based and relevant to all.

Mathematics Education
The link made between the mathematics content and the mathematics education was a strength of the course. A vast majority of the participants elaborated that the development of the teaching portfolio together with the reflections on own teaching had helped the teachers to understand their learners’ strengths and weaknesses. Some mentioned how well they had developed with their reflections from the first to the second year. A further group were enthused with the way constructivism and cooperative learning for example was taught to them.

Other aspects
It might sound strange but many of the teachers were very excited to learn how to plan a lesson properly together with appropriate assessment tools. Some felt enriched by having to write a short research paper on a topic of their choice by first teaching a series of lessons, reflecting on the process and then presenting their findings to colleagues in a short “How I teach” conference which is held annually.

In each professional contact session, teachers are split up into phases during each afternoon session to tackle topics specific to the grade they were teaching. They found these sessions both stimulating and enriching where they could discuss and debate aspects not clearly understood in a topic which affected the whole group.

The module on workshop design and implementation where teachers have to conduct four workshops to other teachers in a community of practice format was enjoyed by most teachers. Not only were they required to choose appropriate activities and relate the activities to the assessment standards but they also had to research the topic thoroughly in order pass on the new content matter to colleagues who were experiencing difficulties.

A unique strength of this ACE is the classroom support visits which take place during the course of the two years. A vast majority of the teachers were sceptical at first about being observed in the classroom, but after feedback from the staff, they have found the visits to be a valuable, productive learning experience. It has also enabled the RUMEP staff to re-evaluate themselves, reflect on their own teaching and consider possible changes to their teaching styles.

Being exposed to basic computer literacy training was another highlight for these teachers, some of whom have never had any experience with computers before. The skills the teachers had gained over the two years had enabled some teachers to develop creative worksheets, class lists for their schools, exam papers and design school report cards.

Materials development was another plus point of the course. Some teachers felt that the materials given to them and the materials constructed by them were helpful, relevant, and practical and enjoyed by learners and colleagues with whom they shared the material. The evaluation of a mathematics text book was for many teachers an activity with great potential not only for themselves but for their schools as well. Discussion of the resource material centred on the criteria such as promoting learner thinking, engaging learners in the
mathematical ideas with the content being aligned with the curriculum and showing the interconnectedness and coherence of the materials was for some teachers very new.

Category 2: Negative aspects of the course

Mathematics Content
There was concern from some teachers that the content taught, should cover all content up to Grade 12 so that a teacher knows what is expected of them in each phase. The course also includes Grade 12 teachers, and a few felt that the content does not address the concerns of teachers in Grade 12. Some teachers also felt that more time should be spent on the research paper.

Mathematics Education
A weakness identified here was that no guidance had been given to teachers to equip them with the necessary writing skills in order to write essays for maths education. Some teachers felt that the portfolios and writing reflections (which they found difficult to do) took precedence over the content being taught.

Other
The normal grievance here and it was expected was that there was too much work covered in a short space of time. Some lecturers gave only short notice for assignments to be submitted. One teacher remarked that conducting workshops was stressful and not easy having to stand in front of senior colleagues. This required thorough planning and preparation. Some teachers also felt that more computer sessions should be scheduled during the first year as the second year was too overcrowded. The lessons for the research module took up a lot of time and there was a breakdown in communication during the submission of the conference papers.

Conclusion
The positive aspects of the course seem to far outweigh the negative aspects as outlined above. A definite strength of the course has been the sharing of the newly acquired content and skills which has excited teachers to go back into their own communities and put into practice what they have learnt. The shift in teaching approach from the traditional, transmission style of teaching to a more learner-centred approach is a further plus point of the programme. The RUMEP ACE course is unique in that our classroom support visits are critical to the success of the programme. The visits not only contribute to the much needed scaffolding and support to teachers, but give the RUMEP staff direct and invaluable insight into the conditions that the teachers have to function. These experiences feed straight into the planning and implementation of the course. The extension into the Collegial Cluster Project by these teachers after the completion of the course where they take responsibility and control of their own professional development is further evidence of the impact of the programme. The partnership with the Department of Education is strong in those districts where the collegial cluster operates which is a further strategy that sustains the project.

Not only has this programme grown from strength to strength but also monitoring the effects of their own classroom practices on their learners’ understanding, thinking and knowledge of
mathematics is being further sustained. These findings indicate that the teachers who have
completed the course feel very strongly that they have been equipped to deal with a multitude
of mathematical aspects as regards classroom teaching from content knowledge, pedagogy
and assessment strategies.

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Mobile technology and the autonomous learning of mathematics

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This paper reports on the progress of the VITALmaths project which was introduced at the 2010 SAARMSTE conference. The project involves the development, distribution and evaluation of short mathematical video clips which have been designed specifically to support and encourage the autonomous learning of mathematics. This paper engages with a number of theoretical and pedagogical issues relating to the design, production and use of these video clips. In addition, synergies between the autonomous learning imperative of the project and the potential autonomous affordances offered by mobile technology are briefly explored.

Introduction

At the 2010 SAARMSTE conference an emerging collaborative research and development project between two teacher education institutions in Switzerland and South Africa was briefly introduced (Linneweber-Lammerskitten & Schäfer, 2010). The project, now known as the VITALmaths project, involves the development, dissemination and evaluation of short mathematical video clips designed specifically to encourage the autonomous learning of mathematics. Students at the University of Applied Sciences Northwestern Switzerland (FHNW) and Rhodes University in South Africa have been developing a bank of such video clips, each of which unpacks a different mathematical concept. Such topics include striking visual approaches to proving the Theorem of Pythagoras; patterns and symmetry generated through tiling activities; elegant visual support for various results from elementary number theory; interior angles of polygons; equivalence of different area formulae; visual insight into the addition of fractions as well as the distributive law.

These silent video clips are purposefully very short (1-3 minutes long) and specifically incorporate natural materials using a stop-go animation technique to develop and explore a variety of mathematical ideas and themes. A dedicated website has now been established to house this growing databank of video clips (www.ru.ac.za/VITALmaths) and these video clips can either be freely downloaded or alternatively streamed directly from the website.

This paper engages with a number of theoretical and pedagogical issues relating to the design, production and use of the video clips. Firstly the notion of autonomous learning is discussed. Secondly, the affordances offered by mobile technology are explored by briefly contextualising the growing potential for mobile learning through cellphone technology within the South African educational landscape. Finally, the implications that both of these considerations have in terms of the design principles of the video clips themselves are discussed.

Autonomous learning

Autonomy represents an inner endorsement of one’s actions – a sense that one’s actions emanate from within and are one’s own (Deci & Ryan, 1987 as cited in Reeve & Jang, 2006:209). Teachers cannot directly provide learners with an experience of autonomy (Reeve & Jang, 2006), but rather they need to provide genuine opportunities that encourage, nurture and support autonomous learning. The VITALmaths project aims to provide just such opportunities through the medium of short video clips.

Although the notion of autonomy is differently conceptualised in different contexts (Davies, 1987), the nurturing of learner autonomy as a general educational goal has been widely recognised by the teaching profession (Chan, 2001). Broadly speaking, learner autonomy is seen as the ability or readiness of a student to take charge of his or her own learning. This entails both a capacity and willingness on the part of the learner to act independently (and in co-operation with others) as a socially responsible person (Dam, 1995 as cited in Chan, 2001:506). As McCombs and Whisler (1989) comment, in order to become autonomous learners, students need to attach personal meaning to learning activities while at the same time they need to develop cognitive and metacognitive capabilities for regulating both affect and motivation. Furthermore, inasmuch as the capacity and willingness for the learner to take such responsibility may not necessarily be innate, it is important to recognise autonomous learning as a developmental phenomenon (McCombs and Whisler, 1989).
As Mousley, Lambdin and Koc (2003:425) succinctly comment, “Autonomy is not a function of rich and innovative materials themselves, but relates to genuine freedoms and support given to students.” Thus, critical elements of the design principles of the video clips take into account both cognitive and non-cognitive dimensions. These video clips unpack a variety of mathematical concepts which are progressively developed while encouraging a desire to experiment, use trial-and-error, formulate conjectures, and generalise results. Importantly, however, they also encourage and support non-cognitive dimensions of mathematical competence such as curiosity and motivation.

In addition, the video clips are purposefully made from natural materials, as opposed to high-tech graphics animations, in order to support autonomous learning on two levels. Firstly, in terms of cognitive access, the use of natural materials is likely to allow for a more direct and personally meaningful engagement with the content of the video clips when compared with the additional abstract dimension associated with high-tech graphics animations. Secondly, learners will be able to personally source all the required material to explore identical or similar scenarios, thus encouraging hands-on mathematical exploration that will have personal meaning for each learner.

An additional dimension to the autonomous learning imperative of the project is our aim to make these video clips available in a number of different languages, including South African indigenous languages. We have already translated a number of video clips into isiXhosa, and this has proven to be an interesting process, one that is likely to provide a meaningful contribution to the debate surrounding the standardisation of mathematics registers in South African indigenous languages.

Specific to the South African educational landscape is our particular interest in capitalising on the ubiquity of cellphones and the potential autonomous affordances offered by mobile technology. Our interest lies not only in the use of cellphone technology as a means of viewing the video clips, but ultimately as their primary distribution platform. Not only will cellphone technology enhance and support the autonomous learning objective of the enterprise, but it will greatly facilitate access to these video materials. In addition, it is anticipated that this innovation will have a significant positive impact for teachers in deep rural settings where access to mathematics resources is very limited.

Mobile technology

There are a variety of mobile devices that have found application within the education arena - Personal Digital Assistants (PDAs), tablet PCs, iPods, and some games devices. However, fuelled by the development of powerful telecommunication networks which support an ever increasing range of data access services, coupled with technological advances and steadily declining costs of cellphones themselves, cellphones have emerged as a viable option for mobile learning.

The annual reports of South Africa’s major cellphone companies reveal that the number of people making use of cellphones in South Africa continues to rise. In March 2009 Vodacom reported a customer base of 39.6 million users, while in December 2009 MTN boasted 26.152 million users. Cell C claimed a total of 6.9 million active users at the end of 2009, and Virgin Mobile announced that it had gained over 200 000 subscribers. According to Oyedemi (2009), cellphone signals reach 99.97% of the South African population. Thus, increased cellphone usage has also resulted in an increase in access to the Internet. This is particularly significant for communities who don’t yet have access to either electricity or computers.

The educational potential for mobile learning afforded by cellphone technology is diverse (Prensky, 2005; Kolb, 2008). Within South Africa a number of projects have already harnessed the ubiquity of cellphone technology to support the learning of Mathematics. A number of these projects are briefly outlined here in order to contextualise the growing potential for mobile learning through cellphone technology within the South African educational landscape.

ImfundoYami / ImfundoYethu is a mobile learning platform that delivers Mathematics education to Grade 10 learners through the instant messaging service MXit. Learners are able to access exercises and additional help. Mathematics teachers log into a web-based management system from which they can distribute exercises to the learners, provide personal support, and monitor both results and learner activity (Vosloo, 2009).
The M4Girls project aims to improve the Mathematics performance of Grade 10 female learners in rural schools in South Africa. Learners are provided with cellphones containing a number of mini videos (2-3 minutes in length), mobile episode animations, and games. All mathematical content is aligned with the South African Mathematics curriculum (Vosloo, 2008).

MOBI™ is a proprietary product that can be accessed through most Java-enabled cellphones. The product aims to provide mobile mathematics education to Grade 10 to 12 learners, and the content is specifically tailored for the South African Mathematics curriculum (Vosloo, 2007). MOBI™ maths provides the user with access to tutorials (in the form of streamed videos), past examination papers with solutions, and an opportunity for learners to use closed chat rooms to form study or discussion groups (Botha, 2007).

Dr Math enables learners to access assistance with their homework assignments by interacting with tutors through the MXit platform. In addition, Dr Math encourages drill and practice of basic skills through games and competitions via the MXit platform (Vosloo & Botha, 2009).

Selanikio (2008) makes the pertinent comment that “for the majority of the world’s population, and for the foreseeable future, the cell phone is the computer”. This sentiment is echoed by Ford (2009) in her pronouncement that “the cellphone is poised to become the ‘PC of Africa’”. The challenge for educators is thus “to capitalize on the pervasive use of cell phones by younger students for educational purposes” (Pursell, 2009:1219). The VITALmaths project aims to take up this challenge and to capitalise on the flexible and versatile potential of cellphones for mobile learning.

Design principles

Of fundamental importance to the VITALmaths project are the design principles on which the video clips are modelled since this plays a critical role in terms of how students are likely to interact with the technological medium. This in turn can dramatically affect the efficacy of the project. There are two distinct tiers to the design process, although they are by no means independent of one another. The first relates to the broader design principles of mobile learning in general, while the second relates specifically to the technical details of the video clips themselves. The overarching consideration behind these design principles is that they support the autonomous learning of mathematics.

Herrington, Herrington and Mantei (2009) identify a number of broad design principles for mobile learning. Of particular relevance to the VITALmaths project, specifically in relation to the autonomous learning initiative of the project, are the following five: (1) the use of mobile learning in non-traditional spaces, (2) Making use of mobile learning both individually and collaboratively, (3) exploiting the affordances of mobile technology, (4) employing mobile learning in contexts where learners are mobile, and (5) employing the learners’ own mobile devices.

In terms of the design principles that relate specifically to the video clips themselves, a purposeful decision was taken to eschew high-tech graphics animations in favour of using natural materials. This design consideration supports autonomous learning on two levels. Firstly, in terms of cognitive access, the use of natural materials should allow for a more direct and personally meaningful engagement with the content of the video clips when compared with the additional abstract dimension associated with high-tech graphics animations. Secondly, learners will be able to personally source all the required material to explore identical or similar scenarios, thus encouraging hands-on mathematical exploration that will have personal meaning for each learner. A number of video clips will be shown in the presentation to frame a discussion around these design principles. A few screenshots are shown in Figure 1 to give an idea of some of the content.
Each video clip develops a particular mathematical theme or concept in a progressive manner. However, it does so in a way that is purposefully not underpinned by specific pedagogical imperatives or predetermined outcomes. Teachers and learners are thus encouraged to use the video clip as autonomously as they desire. This wish is in turn supported by the broad and open philosophy embraced by the design principles on which the video is conceived. It is envisaged that these video clips will be used in the preparation of lessons, for personal conceptualisation of mathematical concepts, and as motivational and explanatory tools, with the emphasis lying on teachers and learners using them as autonomously and independently as they wish.

Concluding comments

The VITALmaths project began as a response to the challenge of developing auxiliary means that could not only release teachers from the frontal introduction to mathematical themes, but also provide an opportunity for learners, particularly weaker learners, to experience genuine and challenging mathematical activities. In order for the videos to be used as autonomously as possible, they need to be short, succinct, visually and intellectually appealing, relevant and mathematically inspirational. A growing databank of video clips has been established, and feedback from teachers and learners relating to the efficacy, use and impact of these video clips is now necessary in order to reflect on and refine the design principles that inform their conceptualisation and production.

To this end, a pilot project in Switzerland was conducted to investigate how a selection of these video clips could be used to support the learning of weaker pupils. A test group was furnished with video clips as an introduction to particular topics while a control group was taught in a conventional manner. The video clips used in the test group were specifically aligned to the mathematical themes covered in the textbooks used by the control group. The pilot study revealed that the video clips resulted in less
time being required to answer questions, thus freeing up time for the teacher to provide additional support for the weaker pupils in the class.

In South Africa a research agenda is presently being established to investigate the manner in which these video clips support the teaching of Mathematics, particularly through the use of cellphone technology. Continued research into the use and impact of these video clips seeks to develop a base for sustained growth and development, while at the same time contributing and participating in the academic discourse surrounding the use and development of visual technologies in the Mathematics education arena.

References


Exploring teaching proficiency using elements of enactivism as an analytical tool: a Nambian experience

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Abstract
As mathematics education research grows globally, theories of teaching, learning and research in mathematics education overlap more and more. This paper reports on a work in progress, where we use elements of Maturana and Varela’s (1992) enactivist theory of cognition as a lens to better understand teacher practice. We use some key enactivist ideas such as “structural determinism”, “structural coupling” and “co-emergence” to make sense of how enactivism as a learning theory can contribute to investigate classroom instructional practices in Namibia.

The emergent enactivist philosophy together with the five pedagogical features of Kilpatrick’s (2001) model of teaching proficiency poses some fascinating research opportunities for mathematics education. This paper is largely theoretical and is integral to the ultimate theoretical framing of a PhD project. This paper aims to highlight and synthesize some aspects of enactivism that will be significant to this PhD research project. It will also offer a discussion about enactivism as an emerging philosophical worldview of learning and researching amongst mathematics educators and researchers. Mason as quoted by Reid (1996) articulates the close interconnection between the many theories of learning we employ as mathematics education researchers. It is thus important to bear in mind that we cannot separate our research into learning from our world views and understanding of learning of mathematics. In this paper, we outline aspects of Maturana and Varela enactivist theory and describe how it has informed and defined our research methodology as a theoretical framework of analysis of mathematics teachers’ teaching proficiency. In particular we will focus on how elements of “structural determinism” and “coupling” inform our research (Sumara and Davis, 1997: 115; Proulx, 2009: 1).

The presentation of this paper seeks to provide an overview of the intended study and invite constructive criticism and advice.

Introduction
Namibia is a post colonial nation and reformed her education system recently after independence in 1990. One of the major aims of the education transformation was to redress inherent imbalances and improve education quality. As such quality mathematics education was the priority to guarantee attainment of mathematical proficiency (Namibia. Ministry of Education and Culture (MEC), 1993). Article 20 of the Namibian constitution stresses Namibian learners should have an equal right to quality (and democratic) education. The education reform included pedagogical changes in the classroom, namely the introduction of learner-centred approaches. Learner Centred Education (LCE) was embraced in Namibia as a
framework for curriculum and teaching at all levels of primary and secondary schooling. In broad terms, this implied a shift in the teacher’s role from that of a classroom expert to being a facilitator of learning. This change also had a direct effect on the teaching of mathematics, with emphasis on learning with understanding as encapsulated in the “Namibian Vision 2030”.

The Vision 2030’s overall goal is to improve the quality of life of the Namibian people to the level of their counterparts in the developed world, that is, “by the year 2030, Namibia should be a prosperous, industrialised and knowledgeable economic-based nation enjoying peace, harmony and political stability” (Office of the President, 2004: 2). But without an educated workforce, this vision might just remain an illusion. Great emphasis therefore needs to be placed on skill development and high quality education that prepares learners to take advantages of a rapidly changing global environment. For this to transpire Namibia needs mathematics teachers who continually improve their teaching practices and nurture a passion for mathematics. In this regard, teachers’ quality is critical to the Namibian national vision as they remain at the heart of achieving the Vision 2030. It is therefore important to have a sense of the nature and quality of current mathematics teachers’ instructional practices in Namibia.

The teaching and learning of mathematics in Namibian secondary schools comprise two categories of schools: a relatively small group of top well performing schools in terms of learners’ mathematical and academic achievement. These are partly former white schools like Etosha secondary school in Oshikoto region, Oshigambo high (mission school in Ohangwena region) and some urban or senior secondary schools. A second cluster includes the bulk of rural and metropolitan schools which are mostly characterised by low performance. The reasons for this state of affairs are complex and varied. Nonetheless, in the context of disappointing results of Namibian pupils, there are beacons of excellence or scattered pockets of successful mathematics teaching. These cases of successful teachers largely motivate this research study. So, central to this investigation is the question: What do the instructional practices of successful Namibian mathematics teachers look like and what are their views on the teaching of mathematics? For the purpose of this study the mathematical focus will be geometry.

Hence, the general objective of this study is to examine selected successful secondary school teachers’ geometry teaching in Namibia. The main aim then is to deconstruct teaching practices and generate accounts of how successful Namibian mathematics teachers teach.

Given the context of Namibian schools and reasons for engaging in this particular study in this paper we will highlight and illuminate the theoretical lens and analytical framework that underpin this study. Furthermore, we will outline a succinct overview of the methodology that we will employ.

Theoretical approach: Enactivism as a theoretical lens
Grounded on the assumption that teachers’ practice is a complex and multifaceted phenomenon that involves a wide range of factors, including planning, actions, proficiency, context, perception and classroom environment (Ball, Bass and Hill, 2004), this study seeks to unpack and document the practice of teaching of successful mathematics teachers within the Namibian education system. The theoretical lens that informs this research study is drawn from an enactivist perspective. The methodological question is how one might see and make sense of teachers’ geometry classroom practice through the lens of enactivism. Thus, the
theoretical framework underpinning the study is that mathematical proficiency for teaching is embedded in the practice of teaching (Kilpatrick et al., 2001; Ball et al., 2004). Currently in the mathematics education research arena, enactivism is a relatively new idea that has been worked with. Its origin can be traced back to the work of Merleu-Ponty (1962), Maturana and Varela (1986) and Varela, Thompson and Rosch (1991), Reid (1996), Begg (2000) and Proulx (2009), just to mention a few. Enactivism has one leg in philosophy and another in psychology. Key dimensions to enactivism are embodiment and phenomenology (Davis, 1996). On one hand, embodiment refers to the developing process of our interactions with the real world outside the formal learning environment. On the other hand, the notion of phenomenology implies that both human biological and historical interactions influence the mind for cognition to eventually take place (Varela et al., 1991). The enactivist theory of mathematics knowing (Proulx, 2009) as an emerging philosophical worldview, builds on the traditional constructivist paradigm that we are all familiar with, and that underpins the Namibian education system. The word “enact” means “to work in or upon” or “to act or perform” (Reid, 1996). Hence, enactivism refers to the ideas of knowing in action. Enactivism is thus a view on cognition in which it is assumed that mathematical knowing and understanding occurs through the mental and physical actions a person performs. Its focus is on the process by which an organism and its environment are interacting. As a theory of learning, enactivism provides us with an interesting analytical lens to look at teachers’ instructional practice.

Conceptually, enactivism has many aspects which suggest that teaching and learning are complex and interrelated. It describes “mathematics knowing” in the context of the classroom as manifested actions as teachers interact with students. Hence, enactivists argue that “learning is through the learner’s acts and is acted upon by the world, and understanding is embedded in doing” (Li, Clark and Winchester, 2010: 16). “All doing is knowing and all [mathematical] knowing is doing” (Maturana and Varela, 1987: 26). From this perspective, learning is seen as a co-evolution of the knower and known that transform both as they interact with the natural world outside the formal learning environment. In this study, we are interested in aspects of Maturana and Varela enactivist theory that will inform our research methodology as a theoretical framework of analysis of mathematics teachers’ teaching proficiency (Sumara and Davis, 1997; Proulx, 2009). It is the theoretical underpinning that provides us with a vantage point to then use Kilpatrick’s (National Research Council (NRC), 2001; Kilpatrick, Swafford and Findell, 2001) teaching proficiency model to analyse teachers’ instructional practice in the mathematics classroom.

Structural determinism or coupling and co-emergence are key ideas of an enactivist worldview that assumes learning as arising from the learner’s own structure as she/he interacts with unfolding circumstances within the classroom environment (Proulx, 2009). In particular, structural determinism refers to notions of partnership, trust, relation and shared actions of the teacher and students. Coupling implies the way in which both the teacher and students learn, co-evolve and co-adapt together (ibid). Co-emergence contends that the process of learning not only depends on the interaction between the environment and the learners, but that the two are inseparable. From these perspectives, learning is not seen as a causal event determined by an external stimuli. This means whatever a learner confronts either in the form of a mathematical task, problem, explanation or intervention is regarded as triggering and invoking his thinking, reactions and eventually learning to take place. In this regard, the teacher is seen as a catalyst for learning to occur but not causing it to occur. This study aims to find out how successful teachers provoke students’ actions and emotions and
influence the learning process. We thus subscribe to the notion that whatever the teacher does in the classroom plays a crucial role in making learners understand mathematical ideas and concepts.

Kilpatrick’s teaching proficiency model as a conceptual and analytical framework

There appears to be little consensus amongst policy makers, curriculum designers and teachers on what constitutes good mathematics teaching practice (Douglas, 2009) in Namibian schools. This study makes use of the Kilpatrick’s model of teaching proficiency to analyse the teaching practice of five successful mathematics teachers. Kilpatrick et al. (2001) propose five interwoven strands of teaching proficiency. These are Conceptual Understanding, which entails comprehension of mathematical concepts, operations and relations; Procedural Fluency, which involves skills in carrying out procedures flexibly, accurately, efficiently and appropriately; Strategic Competence, which is the ability to formulate, represent and solve mathematical problems; Adaptive Reasoning, which is the capacity for logical thoughts, reflections, explanation and justification, and Productive Disposition, a habitual inclination to see mathematics as sensible, useful and worthwhile, coupled with a belief in diligence and one’s own ability to come to know mathematics (p. 116).

Kilpatrick et al. warn that mathematical proficiency is not a one dimensional trait, hence cannot be achieved by focusing on one or two of the strands but that development across all five strands raises the standard of mathematical proficiency, as these strands interrelate and underpin each other (Kilpatrick et al., 2001). For that reason, teachers are advised to structure classroom instructions and instructional activities so that all five strands are embraced in some form or another. Kadijevich (2007) contends that teachers’ classroom instructional practice should focus on mathematical problem posing, representation, reasoning and conjectures as well as problem solving. Moreover, Kapenda (2007) highlights some elements of proficient teaching such as exploration of real-world phenomena, possibilities, application of mathematics structure and appreciation of objectivity.

In this study, the five strands provide a framework for exploring and analysing teachers’ teaching knowledge, skills and abilities. This framework shares similarities with the enactivist framework, in that it highlights learning and teaching as related and complex, and considers teacher and students as partners of a complex holistic classroom environment. In such complex situations, students’ actions, intuitions, interactions, imagining, and explorations and ways of interpreting are oriented by their own structure and understanding of their environment (Davis, 2004). The teacher influences what is learnt by interacting with students, while developing a history together of a mutual relationship through co-evolving and co-adaptation to each other (Proulx, 2009). Both the Kilpatrick framework and enactivist perspective consider mathematical understanding to be embedded in a co-emerging relationship binding teacher and students together in the learning process and teaching dynamic.

Kilpatrick and an enactivist approach call for the teacher to be proficient and actively interacting with the learners in the learning process and teaching dynamic. That is, engaging learners in active dialogue, asking questions that trigger learners’ actions and critical thinking, using current contexts and taking into account learners’ daily life experiences and prior mathematics knowledge.
Research methodology
An interpretive case study research design will be employed involving five selected Namibian mathematics teachers. In order to investigate and deconstruct teachers’ geometric classroom instructional practices “within its real-life context”, and gain “intensive, holistic description and analysis” (Yin 2003: 13), five case study schools will be purposely selected in order to see what teachers are doing in the mathematics classroom. Sampling will be carried out in two stages. In the first stage, a purposive sampling will be used to first select 10 successful mathematics teachers. These are teachers who have consistently maintained a high performance rate in terms of their grades 10 and/or 12 learners’ results in national mathematics examinations in the last three years or so. The second stage involves simple-random sampling to select five out of 10 identified teachers who will form the sample of this study. The following sub-criteria will be used to identify and select the five participants: (1) they must be qualified secondary school (Grade 10-12) mathematics teachers and posses at least a Basic Teacher Education Diploma (BETD) teaching qualification, (2) teachers who are well known and have a ‘good reputation’ amongst peers and the various education regional offices and have at least five years of mathematics teaching experience at secondary school level.

A teachers’ geometry test, classroom observation and structured interviews will be used to collect and generate both qualitative and quantitative data. The teachers’ test will explore participants’ conceptual understanding and procedural fluency of key geometric concepts. It is not yet certain what format this test will take, but the teachers’ participation in the test will be voluntary.

This will be followed by classroom observation to document teachers’ geometric instructional practices. A video camera will be used to record a total number of 15 lessons. In conjunction with the classroom observations, interviews with the teachers will be conducted in order to understand teachers’ perspectives on their practice. These interviews will take the form of jointly analysing the videos and collaboratively negotiating an understanding of their practices. The Kilpatrick framework will form the backdrop of this analysis and the teachers’ practices will be deconstructed according to the five Kilpatrick strands. Very importantly teachers will be challenged to reflect upon their own teaching practice. All interviews will be tape recorded for later analysis. The lessons will be transcribed verbatim. The participants are regarded as co-researchers to review and analyse their own practice. Emerging themes from the observations and interviews will be used to describe in depth the teachers’ teaching practice features. The ensuing narrative will then articulate characteristic features of what makes these participating teachers successful and proficient.

Conclusion
This presentation provided an overview of the presenter’s intended PhD research. The study will draw from five cases of successful teachers with a specific focus on geometry teaching in Namibian high schools. A major limitation of this study is that it will be conducted in only five schools. Nonetheless, the study is aimed to provide some new insights into the teaching practice of successful teachers, and learn from their teaching experiences. The study will also document the kind of mathematical experience successful teachers draw upon in teaching geometry and developing proficient students in mathematics.
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An exploration of the perception of teachers about the training of mathematics teachers for the middle school

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Introduction and background
The primary purpose of the study was to explore the perception of middle school mathematics teachers about the training of mathematics teachers for the middle school. The study focused on the involvement of mathematics teachers in their training and education and the improvement of teacher education programmes to meet the changing trends in education in South Africa. South Africa like many countries is facing a shortage of mathematics teachers. The causes of this include factors such as the content that goes into the curriculum for the training of mathematics teachers, the attraction mathematics holds in the society and overall societal perception about mathematics. There were and there still are, only a few people who opted to train as mathematics teachers. What makes the situation worse in South Africa is that until 1994, official law in the country did not encourage the majority Black population to do mathematics. The training of mathematics teachers was haphazardly handled. Teacher education planning was handled only by officials without the involvement of interested stakeholders. Teachers, student teachers and the community were not involved let alone to know about what constituted an effective training for teachers and if such training was specifically directed to any level along the general school rung. This led to the production of
poorly trained and poorly qualified mathematics teachers. These poorly qualified teachers were however, on the whole, very few for the numerous schools that would otherwise need their services. These teachers form the majority of teachers who continue to teach mathematics in schools. The few who become qualified teach in high schools or are employed by industry and other high paying companies. The lower grades of schooling are therefore left with the unqualified and poorly qualified to teach mathematics. These teachers lack the necessary skills and know-how to lay a sound foundation for mathematics. This was our concern.

The introduction of Curriculum 2005 (C2005) by the Department of Education (DoE, 1996) and its successor the National Curriculum Statement (NCS) (DoE, 2004), introduced a new approach to teaching, a move from teacher-centred to learner centred teaching. This also required teachers to be knowledgeable about new subject content, subject pedagogies and subject curriculum issues (Tobin, Treagust and Fraser, 1998) to effectively teach the subject. This fact also meant that teacher training institutions should incorporate these changes into their teacher training programmes. One wonders however, if these institutions succeeded in doing this in an effective way and if teachers were aware of these issues and what constituted an effective mathematics teacher education programme.

The intention of this study was therefore to explore the perception teachers had about such training.

Research questions

The research was directed by the following questions:

- What are the basic requirements needed to train middle school mathematics?
- What are the problems encountered in the training of mathematics teachers?
- What can be done to improve the training of mathematics teachers?
- What suggestions can be to make the training of middle school mathematics teachers attractive?

Literature Review

During this period of change in education in the country, the policy on curricula for teacher education has not remained static. The Norms and Standards for Educators in 1997/8 were revised; teacher education programmes were required to shift from content to a competence approach. According to policy, teacher education curricular was to ensure that theory and practice were integrated, and that teachers demonstrate not only foundational competence (knowledge of the subject/learning area competence-knowledge of the specialisation) but ways of teaching it. In addition, the qualification framework has changed, and the main qualification for the initial training of teachers is now an integrated 480 credit degree, the B. Ed. Parallel to this qualification however, but at a lower level and catering for older under-qualified teachers, are the National Professional Diploma in Education (NPDE) and Advanced Certificate in Education (ACE).

According to the Department of Education (2000) the cornerstone of Norms and Standards Policy is the notion of applied competence and its associated assessment criteria. Applied competence is the overarching term for three interconnected kinds of competencies, namely:

- Practical competence is the demonstrated ability, in an authentic context, to consider a range of possibilities for action, make considered decisions about which possibility to follow, and to perform the chosen action.
- It is grounded in foundational competence where the learner demonstrates an understanding of the knowledge and thinking that underpins the action taken; and
• Integrated through reflexive competence in which the learner demonstrates ability to integrate or connect performances and decision making with understanding and with an ability to adapt to change and explain the reasons behind these adaptations.

Shulman (1986) proposed a framework for analysing teachers’ knowledge that distinguished between different categories of knowledge, subject matter knowledge (the amount and organization of the knowledge per se in the mind of teacher, pedagogical content knowledge (powerful analogies, illustrations, examples, explanations and demonstrations), and curriculum knowledge (instructional materials available for teaching various topics and sets of programme materials in particular circumstances.) The Department of Education (2003) describes seven roles a teacher must have to be a competent teacher. The teacher must be a learning mediator, interpreter and designer of learning programmes and materials, leader, administrator and manager, scholar, researcher and lifelong learner, community, citizenship and pastoral role, assessor, learning area/subject//discipline/ phase specialist.

Teacher education programmes must satisfy the above requirements to be recognised. This goes without saying that for a teacher to satisfy all the above roles he/she must be involved in the organisation and implementation of the programme.

An example of the component of a teacher training programme is taken from the Faculty of Education, of North West- University, Mafikeng Campus which is made up of:

- Mathematics content
- Issues in mathematics education
- Teaching and learning theories in mathematics education
- Assessment in mathematics education
- Research findings in mathematics education
- Research methods in education
- Research projects in mathematics education (Faculty of Education Calendar, 2008).

Research design and methodology
The research method used in the study was a survey. Both qualitative and quantitative research methods were used.

Population and sample
The population for this research was 30 educators from rural schools of Zeerust Area of the Ngaka Modiri Molema District of the North West Province. Three teachers were selected from 10 schools. The thirty teachers who were purposely selected also formed the sample. Five of these teachers were also interviewed.

Research instruments
The primary tools for data collection in this study were questionnaire and structured interviews. These methods of data collection were guided by the purpose of the study

The type of questions that were used to collect data was both open and closed-ended questions as well as structured interview. The use of interview together with questionnaire was to triangulate data collected. This was to cross-validate data sources, data collection strategies and time periods. Questions were based on:

- Biographical and demographical data of the respondents
- Statements on teacher qualification and the teaching of mathematics
- Mathematics teacher education programmes
- Mathematics teacher training institutions
- Methods of teaching
Analysis and results
Descriptive quantitative and qualitative methods were used to analyse data. Percentages were mostly used to describe findings.

Biographical and demographical data of the respondents
In response to the question on qualifications, 63% of the respondents indicated that they had matric (indication that 37% did not have matric). 10% of them had junior degrees, 17% Honours degree, 7% Higher Education Diploma (HED) and 3% FEC. 77% of the educators had professional qualifications.

Statements on teacher qualification and the teaching of mathematics
80% of the respondents agreed that it was necessary for one to be qualified in the subject he/she taught. Only 57% showed that teachers lacked the required content and methods to teach mathematics. 100% said that they were given experiential training but not all teaching aspects were taught in their training. 100% i.e. all the respondents said they knew nothing about how their courses were structured. They entered the course as prescribed by the institution.

Teacher training requirements of a mathematics teacher
To enter university teacher training programmes for mathematics teachers, 64% of the respondents said requirements were matric qualification in mathematics was essential. 3% gave REQV 13 as a requirement, and 23% said the teachers must have love, knowledge and mathematical skills to qualify to do mathematics! 10% of the respondents did not give any response to this question.

Teacher Education Programmes
Teachers showed their lack of knowledge about mathematics teacher education programmes. 70% did not know about programmes other than their own. 50% did not know about the constituents of their own course expectations except about information that appeared on their transcripts and result slips. The teachers - 100% new the courses should be based on Outcomes Based Education (OBE) but they did not know which aspects of OBE should be treated. However, the teachers - 100% indicated that the higher one qualifies; the better would be ones salary.

On teaching methods, the teachers said methods used by their lecturers were mostly lectures, assignments and projects. They also had teaching practice which was part of the course. Teaching practice they claimed gave them experience in teaching.

Discussions
The fact that 70% of the respondents did not know about the contents of mathematics programmes show lack of interest. It appears student teachers entered mathematic courses without finding out about the courses. The respondents did not know whether the programme should contain courses on assessment, theories, research etc.

Lecturing should move away from teacher –centred to learner –centred teaching and learning. Lecturers should allow student teachers to do more work than always listening to the lecturer. It implies that student teachers are not taught about the application of different teaching methods. The teachers are also not able to use different methods to teach.

The Department of Education (2002) envisages “a lifelong learner who is confident and independent, literate, numerate, multi-skilled, compassionate, with a respect for the environment and the ability to participate in society as a critical and active citizen”. For student teachers to develop these characteristics, it is necessary for training institutions to use
teaching strategies that will help student teachers develop. The DoE (2007) also adds that in-service training or on-the-job training of educators should lead to improvement in one’s qualifications, employability, efficiency and productivity, thus improving and consolidating one’s self-confidence, competence, job mobility and a sense of career direction (Department of Education, 2007). Other issues relating not only to pre-service initial education but also to in-service upgrading programmes is that of assessment of recognition of prior learning. Pre-service and in-service programmes should serve as models that offer quality while increasing access and providing flexible ways to equip teachers in a range of contexts for service to the profession.

Recommendations

It was recommended that student mathematics teachers should be involved in their training and education and that teacher education programmes should be improved and brought up to date to meet the changing trends in mathematics education. The National Teacher Education Audit (1995) found 281 institutions offering in-service and pre-service teacher education to some 481 00 students. These institutions comprised universities, technikons, and colleges of education, private colleges and non-governmental organisations. The audit also concluded that the quality of teacher education was generally poor, inefficient, and cost-ineffective. In order that teachers may perform their duties well, they should have a clear picture of what the time in which they are working wants. Only then will they be in a position to recognise adequately the demands in which the task and the character of their age manifest themselves. They should also know the most important problems of our time and the greatest achievements of modern sciences and arts, i.e they need proper erudition, a sense for reality, and ability so that they are able to adapt themselves to the conditions of our rapidly changing time.

Institutions must improve the quality of their teacher education provision. This can only be possible through work relating to programmes for the upgrading of teachers- the National Profession Diploma in Education (NPDE), and also other upgrading programmes— in particular the Advanced Certificate in Education. The main purpose of this is to ensure that institutions understand the requirements of quality in teacher education programmes, and at best, have put in place the necessary processes to improve quality prior to the national teacher review. In addition, in instances in which there is good quality practice, but financial limitations, the department could assist with funding proposals, or ETDP SETA.

To improve the quality of teaching mathematics, the Department of Education need to provide a quantitative overview of teacher education in Higher Education (HE) institutions. According to the Ministerial report on Higher Education institutions (February 2001), there is a need to ascertain the impact of the restructuring of institutions and of education schools and faculties on the capacity of HE institutions to effectively prepare students for the teaching profession. Capacity conceived here as subtle, less tangible, factors affecting teacher education, including the prioritisation accorded teacher education by the institutions; the commitment of teacher educators to preparing teachers for a changing education landscape; and the competence of teacher educators in providing training within a restructured higher education landscape and a transforming school environment.

REFERENCES


An investigation into learner errors whilst calculating division in problem solving

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This paper focuses on analysing and diagnosing Grade 6 learners’ errors in problem solving that involves calculating by division. The purpose of the study is to deeply identify, diagnose and understand learners’ thoughts in choosing a specific algorithm to solve this mathematical problem. The study was sparked by a continuous analysis of learner performance in benchmark tests through the years. Although a number of general mistakes were picked up in Learning Outcome 1, division was outstandingly interesting. They calculated division making different errors whilst using the same algorithm of representing their calculations in columns like addition and subtraction. Data is collected from Rhodes University Maths Education Project (RUMEPI) Collegial Clusters in the semi rural township and farm schools in Grahamstown, Eastern Cape. It is hoped that the results of this study will be a vehicle for
learning (Lannin et al: 2006) that will contribute to improvement of the teaching and learning of mathematical topics that are sometimes neglected over the most preferred ones like addition and subtraction. If pupils are to be successful in tackling mathematical problems later in their schooling, the one prerequisite is the mastery of the basic concepts in their primary mathematics (Hai & Yusuf).

Introduction

Collegial Cluster Project
The Rhodes University Maths Education Project (RUMEP) focuses on building self supporting communities, whose aim is to improve their own professional practice. To achieve this, the Collegial Cluster Project as one of RUMEP’s programmes places more emphasis on active involvement of teacher communities in their own professional growth, and as agents of change and development in their communities. Although they run their activities independently, they are supported by RUMEP in the form of workshops, classroom support visits, and assessment of learner performance in the form of benchmark tests (pre- and post tests).

In our initial intervention with these schools it was observed that learners were performing very well in Learning Outcome (LO) 1 (Numbers and their relationships) but very low in other LOs. Hence we conducted intensive workshops on these LOs and subsequently learner performance improved. On the other hand, learner performance dropped significantly in LO 1, perhaps due to over emphasis on the newly acquired content knowledge.

This paper is a study in progress, based specifically on the analysis of 2009 grade 6 post tests results, with a focus on learners’ incorrect responses in calculating division whilst solving given problems. The study was sparked by a continuous analysis of learner performance in benchmark tests through the years of our involvement in schools. Although a number of general mistakes were picked up in LO 1, performance in division was outstandingly interesting.

Goals
(a) To investigate why these learners got incorrect answers and also look at their strategies.
(b) Subsequently, we want to plan and implement, firstly, an intervention program in order to address the problems and, secondly, to re-evaluate learner performance thereafter.

Methodology
This research is conducted within the interpretative paradigm and it is qualitative in nature. The goal is to develop an in-depth and thorough understanding and make contextual meaning of how the learners made such errors (van Rensberg, 2001). The analysis will strive to get inside the learners and understand their meanings from within (Cohen, et al, 2000).

This study is conducted using a sample of 5 farm and semi-rural township learners in RUMEP Collegial Cluster schools in Grahamstown, Eastern Cape.

This paper focuses on the following:
1. Analysis of 2009 learner responses
2. Follow up activity
Theoretical framework
Much has been researched on learner mistakes that include misconceptions and errors. Analysing learner errors may reveal the faulty problem-solving process and provide information on the understanding of and the attitudes toward mathematical problems. It can help to diagnose learning difficulties and, in turn, be a starting point for research on the mathematical teaching-learning process (Radatz, 1980). It is hoped that the results will contribute to improvement of the teaching and learning of mathematical topics that are sometimes neglected over the most preferred ones like addition and subtraction. Mistakes are legitimate attempts to understand mathematics; they may also arise out of learners' attempts to make sense of their experiences in their total world (National Centre for Excellence in the Teaching of Mathematics). Although some learners made mistakes in their calculations one could see that there was some sense in their preferred strategies. However, others seemed not to have any clue in terms of visualising the situation. Misconceptions are not created arbitrary but rely on earlier learned meaning systems and they are actually from previous instruction (Nesher, 1987). Therefore, to understand an idea means to incorporate it into an appropriate existing schema although sometimes some new idea may be so different from any available schema (Olivier, 1989). This means, according to Olivier (1989), that it becomes impossible to link it to any existing schema, i.e. assimilation or accommodation is impossible. In analysing these mistakes, it became clear that the schema the learners had was that of perhaps-over-emphasised addition and subtraction. Therefore, when analysing learners’ mistakes it has to be understood that some mistakes that the learners make in mathematics are usually not just mistakes – they are often intelligent generalisations from previous learning (Ryan & Williams, 2007).

When teaching mathematics it is important to build an understanding of symbolic representation because as problems become more complex, this becomes more advantageous and problems can be solved easily (Hiebert, 1989). However, Hiebert further argues that it is not easy for learners to use written symbols, which means they have to establish sound meanings for symbols first. Once this foundation is solid, learners will be able to estimate the answer and then compare it to the solution.

Word problems can play a prominent role in elementary school mathematics because they can provide practice with real life problems and help students develop their creative, critical and problem solving abilities (Contreras & Martinez-Cruz, 2007:498). It is essential to give the learners a variety of word problems involving different operations to solve, so as to build a solid foundation and instil critical thinking from the early years of schooling.

Data analysis
Analysis of 2009 post test learner responses
The following problem was in the post test and I found that most learners were unable to solve it:

The mangoes in the trees above have to be packed into boxes. Each box holds 8 mangoes. If there are 968 mangoes altogether, how many boxes will be needed to pack the mangoes?

It has to be observed that the problem in word problems starts, generally, with literacy. Although some learners were able to read, it was found that they read without attaching any meaning to the text. Therefore, they depended on an explanation and, sometimes,
interpretation to their home language, Xhosa. These were attempts to develop learners’ reasoning in order to be able to solve problems by successfully applying mathematical reasoning to the problem situations they will face as adults (Lannin et al: 2006). Even after these attempts some learners seemed not to make any sense of how to share 968 mangoes into boxes that hold 8 mangoes each, so as to calculate the number of boxes.

Stressed by this learner performance, it eventually came to mind, “Why is the focus on ‘right’ or ‘wrong’ answers only, not looking at why and how they have calculated?” Subsequently, we went back to the scripts in order to analyse them. This analysis of learner’s calculations is based on two constructivist perspectives of learning, i.e.

- Assimilation where the idea is interpreted or re-cognised in terms of an existing schema.
- Accommodation: Sometimes a new idea may be quite different from existing schemas; we may have a schema which is relevant, but not adequate to assimilate the new idea (Olivier, 1989).

With interest and curiosity it was noticed that they calculated division making different errors whilst mostly using the same algorithm, that of representing their calculations in columns like in addition and subtraction. Out of this sample one learner was correct using this algorithm whilst the other 4 were incorrect. This aroused interest even further to look closely at the differences in their approaches to the errors they committed during problem solving (Lannin et al, 2006). It looks like the basic operations schema that came first in their minds are addition and subtraction. Not a single learner in this sample used the usual algorithm of division to calculate this division sum. One would expect the learners to use any of the following conventional methods: 968 ÷ 8;  

\[
\begin{array}{c}
968 \\
\hline
8 \\
= 121
\end{array}
\]

**Example 1: Conceptualised problem solving**

This learner was able to get 121 as the correct answer.

**Analysis**

This shows that the learner was able to visualise and attach meaning to the problem and, thus, understood how to solve the problem. He was able to follow the correct algorithm although lacking the knowledge of basic operation signs. He understood very well that in order to get the number of boxes he had to divide the total number of mangoes by the number of mangoes to be packed in each box. He understood the logic of division as he was able to understand that if 9 hundreds is divided by 8 you get 1 hundred and the remaining 1 is carried over to the tens to give 16 tens. He proceeded to get 2 eights in 16 and 1 eight in 8.

Initially this raised a question whether the operation signs play any important role in solving problems in mathematics. However, if this was grade 3 the learner could use any strategy that he is comfortable with as long as it is relevant and makes sense. It can confuse learners if the teacher tries to discourage learner strategies as they are the only ways that make sense to them. However, a grade 6 learner should be able to represent a division sum with relevant operation signs. In grade 6, “The learner is able to estimate and calculate by selecting and
using operations appropriate to solving problems that involve division of at least whole 4-digit by 3-digit number” Revised National Curriculum Statement Policy (2000:43).

**Example 2: Conceptualised problem solving but incorrect result**

![Image](image)

This learner understood how to solve this problem with a relevant strategy and division operation sign.

**Analysis**
The column algorithm seems to have been entrenched in his mind when performing calculations. However, he had a problem with how to divide. Either he was able to divide 9 hundreds by 8 and got 1 hundred, hence he wrote 100 or he could have got 1 as the number of 8’s in 9, ignored the remainder and the number of 8’s in 6 is 0 and subtracted 8 from 8 to get 0. Or else he calculated 8 – 8 = 0; 6 – 8 = 0 (perhaps you cannot subtract a bigger number from a smaller number, hence he decided to put 0) and then 9 – 8 = 1.

This learner understood very well that in order to calculate the number of boxes, he had to divide the total of mangoes by the number of mangoes to be packed in each box. It is a good skill that he had internalised and able to interpret the problem in order to understand how to calculate using division.

**Examples 3, 4 and 5: Unconceptualised problem solving**

Yackel et al (1990) in Lannin et al (2006) points out that when a child gives an incorrect answer, it is important for the teacher to assume that the child was engaged in a meaningful activity. However, in the following examples, it looks like the calculations were neither meaningful nor realistic; the number of boxes is more than the total number of mangoes. In addition, the errors these learners made are what Olivier (1989) linked to constructivism theory where, sometimes, assimilation and accommodation become impossible as in some cases; division in this case, is different from any available schema. It will be noticed that all these learners used their previous knowledge of addition and subtraction to calculate division. It looks like they had a good understanding thereof although this has led to erroneous results.

**Example 3: Adding 8 to all digits**

![Image](image)

**Analysis**
This learner understood very well that something had to be done to all the digits with the 8. It looks like she understood the bonds clearly but at the same time she visualised a multiplication algorithm. Although in her mind she somewhat decided to multiply each value by 8, she ended up calculating with addition, adding this 8 to each digit.

8 + 8 = 16: She then took 6 and wrote it under units.
8 + 6 = 14: She did not forget to add the 1 ten that remained in 16 and therefore, she added it to have 15 tens. She then took the 5 tens and wrote them under tens.
8 + 9 = 17: She again did not forget to add the 1 hundred that she got from tens to get 18. She ended up getting 1 856 boxes that will be needed to pack 968 mangoes.

**Discussion**
This learner ignored the fact that the number of boxes should be less than the mangoes.
Although an attempt was made to explain the word problem in her home language, which is Xhosa, she could not visualise and make sense that the boxes should be less than the mangoes.

**Example 4: Adding 8 correctly**

Analysis
This learner just added 968 + 8 = 976.
Like the previous example, he has solved the problem with addition. However, this one has a good insight of how to add the 8 to 968 because he added 8 to units only. From the 16 that he got he understood that he had to carry the 1 ten over to the tens and then added it to 6 tens to get 7 tens. Therefore, he got the correct sum which was not the solution to the problem.

Although he is good in his addition algorithm, by adding the 8 does not make sense. He could not see that it is impossible to pack 968 mangoes in 976 boxes with each box carrying 8 mangoes. Therefore, he did not attach any meaning to the problem.

**Example 5: Subtracting 8 from each digit**

Analysis
This learner decided to subtract 8 from each digit:

- She was able to subtract 8 from 8 to get zero
- She then subtracted the same 8 from 6. As 6 is less than 8, she borrowed from the hundreds and now she had 16 and she was able to subtract 8 from 16 to get 8.
- She then decided to just bring down the last 8.

Perhaps she has an insight that the number of boxes should be less than mangoes, hence she decided to subtract. Nevertheless, she lacks an understanding that this 8 she has subtracted represents only 1 box. Therefore, she should have rather subtracted other 8’s from the remaining mangoes till she remained with zero mangoes. Although this would have been a very long strategy, at least at the end she would be able to get the number of boxes.

2. Follow up activity
After analysing the above learner errors a different set of schools was used but now with a simpler division problem that involved smaller numbers. The reason for this group of learners was to find if there would be a common trend in order to draw conclusions. The problem was as follows:

Mother baked 480 small cakes and packs them into plastic bags to sell in her Spaza Shop. If each plastic bag holds 3 small cakes, how many plastic bags will she need?

Looking at their responses, the problem remained the same.

**Correct visualisation of the problem but with challenges**

The following learners were able to visualise the problem and also understood which operation sign to use:
Ignoring the remainder
Dividing from right to left
Some of those who managed to visualise that they had to divide had a tendency of dividing starting with the units and moved to the left. These are sometimes learners who did not use the division algorithm. For example, in the second example underneath the learner used the algorithm which is supposed to be that of multiplication.

The challenge in both of the following examples was that, perhaps, they did not know what to do with the remainder and decided to ignore it, especially with the first example:

For example, this one divided 0 by 3 and understood that it should remain 0. However, when dividing 8 by 3 she correctly got 2 and 4 by 3 and correctly got 1 but ignored the remainders in both cases. The concept of zero is well understood here as when she wrote her answer she knew that she cannot start writing a number with a zero, hence she wrote 21. However, she ignored the fact that the zero was standing for units and 4 for hundreds.

This calculation is the same as the above but the learner managed to remember to carry the remainder over to the hundreds (although it is 1 instead of 2) hence he has 14 hundreds. He got the number of 3s in 14 as 4 which is correct. Since the hundreds are the last value in this number, perhaps he did not know what to do with the remainder and decided to ignore it.

Correct operation but incorrect computation

In the above examples the learners have used the correct algorithm for division but the challenge on top of ignoring the remainders was with the concept of zero. They seem not to understand the concept of zero and if you divide nothing you get nothing. For example in this example the learner divided 0 by 3 and got 3. It is not clear in the second example how this learner got 8.

Correct visualisation of the problem and Correct learner strategies

Example 1
Although the focus was on learner errors, looking at some learners who produced correct responses could not be ignored. Some of learner strategies were relevant and produced correct answers but needed to be refined to prepare them for bigger numbers. Although the statement, 480 x 3, is confusing as it would not give the correct result, she managed to get the correct answer at the end using multiplication.
She found using the multiples of 10 easier, which then is 10 bags with 3 small cakes each = 30 small cakes. She carried on like this till she got 450 small cakes and 150 bags. It is not clear now why she multiplied 10 by 1; perhaps she saw that there is 1 group left. It looks like this learner might be avoiding the operation sign ÷ in all her calculation or perhaps a division sign has a threatening image in her mind. Nonetheless, her multiplication strategy has proven that division is an inverse of multiplication.

Example 2
The same strategy was used in this example. She has a picture of what has to be done as she listed the 3’s with the idea in mind to get to 480. She listed 16 threes, added them and got 48. She wrote this 16 but later decided to cancel it. If she had given this some more thought she would have seen that 48 × 10 = 480 and would have got 16 × 10 = 160. Instead, she decided to divide 48 by 3 and got 19. She did not ignore the remainder but got 9 as the number of 3’s in 18.

Conclusion
All these experiences in division made us to look back and think in relation to learners’ errors, trying to speculate the root and the cause of the problem. Teachers must avoid giving the learners more activities thinking that this would address learners’ mistakes; they must try to understand why learners make mistakes by looking at their solution strategies. Generally, learners were unable to internalise the situation, make sense of it, then think of and apply a relevant strategy to solve the problem. The fact that they gave abnormally incorrect answers shows that, perhaps, they did not understand the word problem. In some cases learners struggled to read the word problems. In other cases, they could read but without making sense of the text. We, therefore, recommend that word problems should be an integral part in the teachers’ teaching practice in order to develop a reading culture so as to develop critical, logical and creative thinking skills.

It looks like there has been an overemphasis on addition and subtraction algorithm over multiplication and division.

This is of course a challenge to us as service providers who have access to develop teachers in workshops right into the classroom for support, to plan a strategy of addressing this problem. There should be a flow and integration linking multiplication and division in the teaching practice.

References
ABSTRACT

This paper reflects and discusses teacher and learner perceptions on the use of isiXhosa, one of the nine official African languages in South Africa, as a language of instruction in school science and mathematics in three selected primary schools in the Western Cape, South Africa. Data were collected by means of interviews with teachers and learners. Whilst the paper indicates that both teachers and learners have a positive disposition towards the use of isiXhosa as a language of instruction in science and mathematics, it also acknowledges the existence of pedagogical, linguistic and structural challenges.

Introduction and Background

The issue of the language of instruction in mathematics and science has received worldwide
attention in education circles. Much research has been done particularly on the influence of and the importance language in mathematics and science learning, including generally the role that language plays in the education of non-native speakers of English (Clarke and Izard, (1993); Durkin & Shire, (1991); Hunting, (1988); Orr, (1987); Pimm, (1987); Stephens, Waywood, Clarke & Izard, (1993); Setati, (2005); Makinde & Olabode, (2006). Setati (2005, 2008) also argues that language has always been used as a political tool for subjugation of people on the one hand and on the other hand language has also provided a tool of resistance against this domination. For instance, the spark that ignited the powder keg of student resistance in South Africa in 1976 was the compulsion to use Afrikaans, which was viewed as the language of the language of the oppressor in black classrooms. Hence the issue of language in multilingual societies has always been a contested terrain. Studies by Setati, (2008) on parent, teacher and learner preferences on the language of instruction indicate that they prefer English because it is a “universal language” and provides access to knowledge because “textbooks are written in English, … [and] the question papers are in English.” Iyamu & Ogiegbaen (2007) focused their study on teachers and parents’ attitudes to the mother tongue as language of instruction in Nigeria whilst Ndamba (2008) also conducted a study on parents and learner attitudes towards the use of the mother tongue as the language of learning in Zimbabwean schools. The findings of Ndamba’s (2008) study echo those of Setati (2008) in that both parents and learners preferred English as the language of instruction. However, Nigerian teachers in Iyamu & Ogiegbaen’s (2007) study take a contrasting position in their preference for the mother tongue whilst parents have maintained the same position as that of the previously mentioned studies for preferring English as the medium of instruction. In contrast to the findings of these studies, empirical evidence from international research indicates that learners who are taught in their mother tongue generally do better than learners who are taught in English in these subjects (Sentson, 1994; Langenhoven, 2005; Nomlomo, 2007; Mwishineike, 2008).

The Language of Instruction in Tanzania and South Africa (LOITASA) Research Project

This paper reports on the views of grade 4 teachers on the use of the learners’ home language in mathematics and science teaching. It is based on a joint research project of three universities, namely, the University of Daar es Salaam in Tanzania, the University of Oslo in
Norway and the University of the Western Cape in South Africa. The project was established in 2003 “...to explore the use of African languages (Kiswahili and isiXhosa) as media of instruction in Tanzania (Kiswahili) and South Africa (IsiXhosa)” (Nomlomo, 2007, p.2). The University of the Western Cape researches the use of isiXhosa, the dominant African language in the Western Cape, as a language of instruction in mathematics and science in primary schools, whilst the University of Dar es Salaam researches the use of KiSwahili in secondary schools.

The project is in its second phase since its inception in 2003. The first phase of the project which focused on science and geography ended in 2006. The second phase of the project, which commenced in 2008, substituted geography with mathematics. The project followed an experimental research design and focused on the teaching of mathematics and science through the medium of English and isiXhosa from Grade 4 – 6. This initiative is in response to the low numbers of learners, particularly from disadvantaged backgrounds, who pursue careers in the fields of mathematics and science in tertiary education.

In both developed and developing countries mathematics and science are regarded as priority areas for economic and technological advancement, and for improving people’s lives and nation building (Volmink, 2010; Wedikkarage, 2006; Ogunniyi, 2005; Rogan and Grayson, 2003). However, there are still challenges and inequalities in the education system due to the legacy of apartheid in South Africa. One of the challenges is the use of English as the main language of instruction for the majority of black learners to the exclusion of their home languages after Grade 3.

Some writers state that there is reluctance and resistance to the use of African languages in mathematics and science teaching, ostensibly due to their lack of global status and the lack of appropriate terminology in the indigenous languages (Bunyi, 1990; Elugbe, 1990; Hameso, 1997 and Prah, 2003). This paper contends that there are more benefits than disadvantages in using an African language (isiXhosa) in mathematics and science teaching. It argues that although the use of isiXhosa has both cognitive and affective benefits, there are some challenges that have to be taken into consideration. It is underpinned by the following research questions:
What do teachers and learners perceive to be the positive contribution of the use of isiXhosa in mathematics and science teaching and learning?

What are the perceived challenges in the use of isiXhosa in the teaching and learning of mathematics and science?

Research Method

For the purpose of this paper, data were mainly collected by means of interviews from three grade four classes in three different primary schools. All these schools are located in disadvantaged residential areas of the Western Cape Province of South Africa. In the first phase of the research project two Grade four science teachers and ten learners were interviewed while the second phase focused on one Grade four mathematics teacher and five learners. In both cases the interviews were semi-structured and they focused on teachers’ and learners’ perceptions in relation to the research questions stated above.

The data were video and audio-recorded and subsequently transcribed. Data analysis took the form of themes whereby teachers and learner responses were categorized according to emerging themes and subthemes corresponding with the research questions stated above.

Teachers and learner perceptions on the use of isiXhosa as a medium of instruction in science

Teachers and learners generally displayed a positive disposition with respect to the use of isiXhosa as a language of instruction and learning in mathematics and science. Their positive attitudes can be construed as recognising the cognitive, pedagogical, the affective and socio-cultural benefits of teaching and learning through the home language. However, they also recognised the existence of structural and epistemic challenges.

Pedagogical and learning benefits

The positive benefits of using isiXhosa as a language of instruction, according to the teachers, manifest themselves in terms of active learner participation, better understanding of mathematical and science concepts, improved strategies of teaching and improved parental
involvement. As one science teacher puts it:

Kuyabanceda kakhulu (ukusebenzisa isiXhosa)... iba yiklasi yonke ephendulayo... bayalandela kakhulu... Nabazali bayayinika inxasos, ... bayayijonga le nto uyenzayo, ... batshintshile kunakuqala,... babuye (abafundi) bethetha more than ubumxelele apha eklasini.

It helps them (learners) a lot (using isiXhosa) ... the whole class responds... they understand very well. The parents give support,... they look at what you are doing, they have changed than before, ... they (learners) come back talking more than what you told them in class.

The mathematics teacher who was interviewed, corroborates the science teacher’s perception on the use of isiXhosa as a language of instruction. He expressed a positive disposition towards the LOITASA project because of its contribution in seeking to determine the best approach to the teaching of such a difficult subjects as mathematics and also to facilitate conceptual and procedural understanding in mathematics. As he put it:

Ndiyayixhasa le projekthi ngoba iyasinedisa thina singootishala ukuze siphucule indlela abaqhuba ngayo abantwana kwimathematics.
Ndiyaqwalasela ukuba abafundi bathabatha inxaxheba kakhulu kwaxxoko ngemathematics baze baphendule imibuzo ngcono xa besebenzisa ulwimi lwabo.
Ndikwaqwalasela ukuba baqonda ngcono kwesi sifundo xa befunda ngolwimi lwabo.

I support the project because it seeks to assist us as teachers to improve the performance of learners in mathematics. I can see that learners participate more in discussion in mathematics and respond better to questions when they use their own language. I can observe also that learners understand the subject better when they learn it in their own language.

Similarly learners perceived the use of isiXhosa as assisting them to understand subject content and to participate with confidence in mathematics and science lessons. Regarding academic achievement, learners did not only
perform better in mathematics and science but showed confidence in terms of their competence in English. They claimed that some of them were doing better in English and in other subjects (taught through the medium of English) than some of the learners who were taught mathematics and science through the medium of English. Such comments are not surprising given their positive attitudes towards their home language (isiXhosa).

Siyabogqitha aba be-English ngoba siya-understand (a), sigqibe (umsebenzi) ngokukhawuleza.

We do better than the English learners because we understand better and finish (work) quickly.

Learners also showed interest in learning English as a second language while retaining their home language (isiXhosa) as a medium of instruction. So they perceived isiXhosa as a good foundation for learning English. Such responses reveal their intuitive awareness of additive bilingualism instead of subtractive bilingualism and the cognitive benefits of the mother tongue as reflected in the following utterances:

Kufuneka ilanguage yakho uyifunde,... awunakufunda ezinye i"language" ungayazi eyakho. Kufuneka uqale ngeyakho, ulandelise ezinye.

You must learn your language,... you cannot learn other languages if you don’t know yours. You must start with your own (language), and thereafter learn others.
Affective Benefits

Both teachers and learners displayed positive feelings towards isiXhosa as a medium of instruction in mathematics and science. For example teachers indicated feelings of comfort in the use of IsiXhosa in teaching because they do not have to spend time doing explanations of concepts nor analyzing and simplifying questions for learners during assessment. This implies that the mother tongue is a useful tool for communication and conception. As one teacher put it:

Ndiziva kamnandi ndonwabile ngoba andichithi xesha lininzi ndicacisa. Iyandonwabisa ukubona abantwana bezihlalutyela ngokwabo imibuzo ye-mathematics beqonda intsingiselo yemibuzo. Loo nto indothulela umthwalo yenze kube mnandi ukufundisa.

I feel good and happy because I do not have to spend a lot of time explaining. I feel happy because learners analyse mathematics questions on their own without my assistance and understand the essence of the questions. That makes things easier for me and makes teaching a pleasant experience.

For learners, learning through the medium of isiXhosa boosted their self esteem and confidence. These learners showed better confidence than their counterparts who learnt through English. They perceived isiXhosa as a language that could contribute to their advancement in their lives. They also showed pride in their language as a medium of instruction as can be gleaned from the following utterance by one learner:

Besifuna ukuthi gqi nathi ngesiXhosa kwiNatural Science nakwi mathematics... sibe zii-Black.... umntu wokuqala esiya phezulu, siye kwi-space, singaziyekeli. Sifuna ukungenela i-competition, sifuna abanye abantwana, sibabonise ukuba siftunda kanjani ngesiXhosa.
We wanted to come up with isiXhosa in Natural Science and mathematics... and become Blacks... the first black person going up,... going to space, (and) don't underestimate our abilities. We want to enter for a competition, we want to show other children how we learn through the medium of isiXhosa.

The learners also showed enthusiasm and eagerness to continue with isiXhosa as a medium of instruction beyond Grade 6. When asked how they felt about having to switch over to English as a medium of instruction in Grade 7 at the end of the project, learners responded that they wanted to go to higher educational levels with isiXhosa as a medium of instruction. They aspired for life advancement through their own language (e.g. becoming astronauts, doctors, social workers, singers, etc.). The learners displayed positive self-concepts in terms of competing with other science learners internationally. They did not associate isiXhosa with jobs of low standard; instead they were positive about their lives in the economic world. They also showed pride in learning through isiXhosa, and they wished for publicity (i.e. to let people know that they were taught in isiXhosa that is sometimes marginalized by other people).

Siziva singayithandi kuba thina besifuna ukuqhubeka side siphume apha eZama, ngoba besifuna nathi ukuba siphumelele, sifunde zombini ezi-language...

We don't like it because we wanted to continue until we leave Zama, because we want to be successful, to learn these two languages...

Challenges of using isiXhosa as a medium of instruction in science and mathematics

Teachers and learners reported that, whilst, in general, the benefits far outweigh the negatives in teaching and learning in isiXhosa, there are challenges that need to be overcome. The main challenges mentioned by the teachers and learners were linguistic and structural. The
challenges include the following: (i) specialized science and mathematics terminology, (ii) terminological ambiguities and (iii) linguistic variation in isiXhosa as a spoken language.

Specialized scientific and mathematical terminology

In both mathematics and science education, one of the challenges is that there are no direct terminological equivalents in isiXhosa. In science, for example, terms such as photosynthesis, evaporation and others do not have isiXhosa equivalents. In this regard, Fischer, Weiss, Tshabe & Mdala (1985, p.453) translate the term “photosynthesis” as: “ukuguquka kwekhabhoni-diokside okwenziwa ngeklorofili nelanga ibe ziikharbohidrate/ changing of carbon dioxide made of chlorophyll and the sun into carbohydrates”. Apart from the adoption of English terms such as chlorophyll, carbon dioxide and carbohydrates, the translation is an inadequate description of the process of photosynthesis. This was supposed to be what Jokweni (2005) and Mbekwa (2009) refer to as the semasiological approach to translation which employs a descriptor as a translation device. In this case however, the correct definition of photosynthesis is missed.

Secondly, there are scientific terms which, when translated into isiXhosa, become unfamiliar in the everyday isiXhosa language use (e.g. “inkqunto/actual thing” for “matter”). Although translations of such words have relevant and appropriate meanings, they become inaccessible to learners as they do not hear them at all in their surroundings. Teachers confirmed the difficulty of using unfamiliar words which influenced them to make use of loan words from English.

Ulwimi olusetyenzisiweyo luntsonkothile, luntsonkothile kakhulu... nalapha esiXhoseni akhona amagama endingawaziyo... Ndisebenzisa isiXhosa
ngaphandle kwelo gama kuthi kube nzima ukulicacisa, ... umzekelo i’nkqunto” .... Ndibhenele esiNgcsini but ndithethe isiXhosa.

The language used is complicated, very complicated… there are words I don’t know even in isiXhosa…I use isiXhosa except for that particular word which is difficult to say in isiXhosa, perhaps it becomes difficult to explain it, ... for example “inkqunto/matter”… I resort to saying it in English but explain it in Xhosa.

Likewise in mathematics, examples of terms which have no direct isiXhosa equivalents are terms like “place value; flow diagram; prime number” translated into isiXhosa as “ixabiso-ndawo; umzobo wonxbelelwano-manani; inani elingenazahluli.” These isiXhosa translations are descriptors which capture the conceptual connotations of the English mathematical terms and hence facilitate conceptual understanding. It is therefore important that the translator should be someone who is a subject specialist and also a first language speaker of isiXhosa in order to capture the meaning and nuances of the scientific and mathematical terms.

The mathematics teacher who was interviewed indicated that the isiXhosa terms are not usually used in classroom mathematical discourse and hence are intimidating to learners. It is incumbent then for the teacher to help learners understand what these terms mean and hence also needs to give the English equivalents and diagrammatic representation for them where applicable. The teacher puts it thus:


These words [isiXhosa] are not frequently used in the classroom. They are also not part of everyday language at home and also not in use in day to day activities of the learners and thus do not form part of the learners’ vocabulary. These
Terminological ambiguities in science and mathematics

Challenges relating to the science language include the absence of appropriate terms in isiXhosa, multiple meanings of certain isiXhosa terms, scientific symbols, etc. For example, in cases where there are equivalent terms in isiXhosa, one may get the same translation or meaning for different terms e.g. the two colours “blue and green”, according to the English/Xhosa Dictionary (1985) have the same translation in isiXhosa i.e. “luhlaza” although “luhlaza” has two different connotations referring to both the colour blue and the colour green. Likewise, the colours “purple” and “violet” have the same meaning “mfusa”. It then depends on the translator to distinguish which colour is referred to when using the term “luhlaza”.

Similarly these terminological ambiguities exist in mathematics, although no mention of this was made by the mathematics teacher. An example of such an ambiguity could be the term “ixabiso” which may refer to both price or cost and value in English.

Dialectical variation in isiXhosa

Dialectical variation in isiXhosa was another challenge in reading the translated text. Apart from urban and rural variants, isiXhosa has nine mutually intelligible dialects namely, isiGcaleka/isiNgqika, the standardized dialect, and the non-standardized dialects; isiMpondo, isiMpondomise, isiBaca,
isiThembu, isiNtlangwini, isiHlubi, isiCele, isiXesibe (Nomlomo, 1993). One of the teachers who grew up in one Cape Town township found it difficult to understand certain terms which were used in the learner-support materials. Her concern links with the perception that rural language variants are more difficult and richer than urban variants.

The other teacher displayed an awareness of linguistic variation and suggested that translations should take into consideration the common dialect or variant spoken in a particular area so that learners are not removed from the variant they use in their speech communities. As she put it:

Ngaske xa ku”translatwa”i-English to isiXhosa ibe sisiXhosa esithethwa kuloo ngingqi ukwenzela ukuba abantwana kungafunekile ukuba batolikelwe isiXhosa…. (Umntu otolikayo) adibane notitshala, ohlala apha eKapa, othetha esi siXhosa salapha eKapa sisisebenzisayo ngoba isiXhosa asifani.

I wish that when translation is done from English to isiXhosa the language (isiXhosa) spoken in that particular area be used so that there will be no need to retranslate isiXhosa to learners… (The translator should) contact the teacher, who is speaking the Cape Town isiXhosa variant we use here because isiXhosa is not the same.

In addition, the isiXhosa spoken in urban environments is dissimilar or anglicised as compared to the isiXhosa spoken in rural environments. To overcome linguistic and conceptual problems that learners are confronted with, the teacher proposed codeswitching, which implies the mixing of isiXhosa and English terms as an alternative teaching strategy.

Learner Perceptions on the Use of IsiXhosa for Science and Mathematics learning
Challenges of using isiXhosa for learning

Teachers’ experiences on teaching mathematics and science in isiXhosa encapsulated pedagogical and linguistic challenges. On the other hand learners mentioned structural challenges as impacting on their learning of science and mathematics through the medium of isiXhosa. These structural challenges include lack of laboratories and libraries in their community. They did nor refer to the lack of laboratories and libraries in their schools nor did they expand on their expectations on these challenges. Seemingly these learners would be satisfied with the general library serving some of the communities surrounding them. They articulated their frustration in this way:

Apha ku le ndawo sihlala kuyo akukho librárý. Mna ndirhalela ukuba sibe nazo izinto zoku experimenta.

There is no library where we stay. I wish we had tools for experimentation.

One can observe from the above utterances from learners that their main challenge is infrastructural whilst those of teachers are educational and linguistic.

The learners’ responses could be attributed to their understanding and need to learn science through experimentation and mathematics from books and as far as they are concerned, these resources can only be found in laboratories and libraries.

Implications of using isiXhosa in the teaching and learning of science and mathematics

In addressing the question of how teachers would resolve the challenges they were confronted with, they made the following proposals.

Discussion and conclusion

This study shows that both teachers and learners recognise the cognitive benefits of using their home language (isiXhosa) in the teaching and learning of science and mathematics. As shown in the discussion above, they have indicated that the use of isiXhosa facilitates active
learner participation and better conceptual understanding of science and mathematics. This indicates the importance of language proficiency in the learning of school subjects such as science and mathematics. This ties in with Cummin’s (1996) notion of the Cognitive Academic Language Proficiency (CALP) which proposes that the home language is a good foundation for effective learning.

From this study it has become clear that it is feasible to use an African language as a medium of learning and teaching in school science and mathematics despite the general perception that African languages cannot be used in science and mathematics education because of their perceived lack of global status and appropriate terminology. Similar studies like the Six Year Primary School Project (SYPP) in Nigeria in the 1970s (Bamgbose, 2005), the LOITASA project (Qorro, Desai & Brock-Utne, 2008) and a recent study in Ethiopia (Yohannes, 2009) have shown that it is possible to produce teaching and learning materials in local African languages.

Given that science and mathematics are priority areas in the South African education system, it is imperative that all learners have access to these subjects in order to participate in the economic and technological development of the country. Access to these subjects is possible if teaching and learning is through a familiar language, viz. their home language as suggested by the teachers’ and learners’ responses. However, it is clear from the discussion above that there are challenges surrounding the teaching of science and mathematics through the medium of isiXhosa. The pedagogical challenges can be addressed in various ways such as exemplification, which implies giving examples in cases where there is uncertainty and lack of clarity of scientific terms and diagrammatic representation, the use of pictures and drawings and the use of models or samples to illustrate scientific and mathematical ideas and objects.

The linguistic challenges on the other hand may be addressed by making use of codeswitching and borrowing or use of loan words where isiXhosa terms are obscure in meaning or difficult to understand. Consultation with subject teachers and parents including policy makers and curriculum designers is important in addressing the issue of acceptable and accessible scientific and mathematical terminology.
References


What effect will dialogical argumentation have on Grade 9 learners’ conceptual understanding of selected meteorological concepts when used as an instructional method in a science classroom in the Western Cape, South Africa

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Rapid environmental changes with disastrous consequences in many parts of the world have led to a greater public awareness of the need to conserve the environment for human welfare. The recent Tsunami in East Asia, the earth quake in Haiti, the floods in various regions of the world (including South Africa) to name a few, have been a matter of great concern worldwide. This is even more so since a lot of the environmental disasters e.g. global warming, acid rain, desertification, environmental pollution, loss of biodiversity in many parts of the world have resulted largely from scientific and industrial activities. An important goal of environmental education is to help learners develop valid understanding of the environment as well show responsible attitudes towards that environment. It seems that for learners to develop the right attitudes towards the environment they need to be introduced to environmental issues early in life. Research points to an underachieving pattern amongst the
majority of children in the Western Cape. Research points to an underachieving pattern amongst the majority of children in the Western Cape.

The rationale for introducing children to meteorological literacy and environmental education during the early school years cannot be overstated. This is based on the premises that early exposure would provide them opportunities to learn the various ways by which their environment can be conserved and used to improve their quality of life. By the same token it is expected that such an early exposure would enable them to appreciate and develop desirable attitudes to their environment. In other words, children must develop a sense of respect and caring for their natural environments during their first few years of school life or be at risk for never developing such attitudes. Learning Outcome 3 of the Revised National Curriculum Statement Grades R-9 science curriculum expects learners to be able “to demonstrate an understanding of the interrelationship between science and technology, society and the environment” (Department of Education, 2002:10).

Opinions vary about what grade learners should be introduced to environmental (meteorological) literacy. While some argue for the pre-school or the first grade, others think of the third grade or later (Glynn, 2000). Whatever the case, it seems reasonable that children should be introduced to meteorological concepts very early in life. Environmental education based on life experiences should begin during the very early years of life. Such experiences play a critical role in shaping life-long attitudes, values and patterns of behavior towards the natural environment. It is perhaps the late start of environmental education that has brought about the poor attitudes that many show to their environment. It is in this regard that the present study will undertake to explore some meteorological concepts among grade 9 learners in the Western Cape.

The aim of the study is to determine grade 9 learners’ conceptions of selected meteorological concepts. A related aim is to determine the learners’ attitudes towards their environment. The study is underpinned by dialogical argumentation theoretical framework as espoused by Toulmin’s (1958) Argumentation Pattern (TAP) and Ogguniyi’s (1997) Contiguity Argumentation Theory (CAT). The two theories accord with Vygotsky’s notion of constructivism whereby an individual learns or acquires new experiences from his/her interactions with his/her physical or socio-cultural environment. The TAP construes learning in terms of the ability to support one’s claim with valid evidence or reason while the CAT construes learning as a product of self-or cross conversation and reflection. This study would explore the application of both the TAP and CAT in the context of classroom discourse dealing with selected meteorological concepts.

A survey will be conducted in 3 secondary schools in the Western Cape to explore learners’ ideas about, and attitudes towards their environment. This will be followed by implementing a dialogical argumentation instructional method (DAIM) to enhance learners’ understanding of selected meteorological concepts in one secondary schools in the Strand. The effectiveness or otherwise of the DAIM will be determined using a measurements instruments such as: Meteorological Literacy Test (MLT), an open-ended questionnaire, a semi-structured interview and classroom observation schedule. The data collected through the various instruments will be analysed in terms of appropriate quantitative and qualitative measures.

Introduction: This research study is still in its developmental stage and all proposed plans are suggestions to develop the study into its formal and final stage. Some instrumentation,
questionnaires and worksheets has been develop and is still in it pilot form. The actual research study will be conducted in the first semester of 2011 and will be use to write a full thesis for submission for the M Ed. Degree at the University of the Western Cape in South Africa.

Background: An important goal of environmental education is to help learners develop valid understanding of the environment as well show responsible attitudes towards that environment. The Revised National Curriculum Statement Grades R-9 (Schools) policy of 2002 for Social Science promotes the kind of learner that is envisaged and that can “develop an awareness of how to influence our future environment by confronting and challenging” environmental inequalities (RNCS, 2002).

According to Schreuder & Le Grange (2002) the majority of environmental problems in South Africa are related to the educational crisis caused by the previous apartheid policies of the South African government. Educational resources were not equally distributed and only benefited the minority of the population, whereas the majority received a poor education. This resulted in environmental illiteracy, lack of environmental sensitivity and over-exploitation of natural resources. With the adoption of South Africa’s final constitution, human rights and social accountability has been linked to environmental issues.

Purpose of the study: The main purpose of the study is to investigate, the effectiveness of an Argumentation-based instruction (A-B) instruction in enhancing grade 9 learners understanding of, and awareness of weather patterns and selected meteorological concepts. A related aim of this study is to investigate the effect of the A-B instruction on grade 9 learners level of understanding and the importance of meteorological literacy and how it affects their daily lives. Another related aim is to determine the learners’ understanding of weather and climate phenomena and how human beings interact with these phenomena on a daily basis. More specifically the study will attempted to determine the effectiveness of an A-B instruction on learners understanding of weather and climate related issues. The emphasis is then placed on how learners relate to selected meteorological concepts and interpret them in the current school curriculum. The study also aims to make learners aware of the importance of certain weather concepts and how they interpreted the predictions of weather around them.

Research Questions: The following research questions will be addressed in order to assess the conceptions and understanding of meteorological concepts among grade 9 learners in secondary schools.

1. What meteorological concepts do grade 9 learners hold?
2. Are grade 9 learners’ meteorological conceptions related to their age, class or gender?
3. What are grade 9 learners’ ideas and attitudes towards their environment?
4. What effects does a dialogical argumentation instructions have on grade 9 learners’ meteorological conceptions and attitudes towards their environment?

Two other studies conducted by the NEETF (National Environmental Education Training Foundation) in 1990, claims that meteorological theory based literature do help in promoting
a difference in environmental education, and that learners do benefit from these illustrations. These two studies reported that Environmental Education develop a certain kind of skill that help with understanding science content i.e. meteorological concepts better and promotes global warming awareness among learners (Leidermann & Hoody 1998). Other studies have indicated that by linking school curriculum activities, worksheets, and outdoor classroom activities to local environmental conditions the learners make real-world connections, allowing the material to be made more meaningful, tangible and relevant in terms of increasing their interest as well as decreasing discipline problems (Battersby, 1999; Glynn, 2000; Krynock & Robb, 1999). The gains in learners’ achievements and motivation are attributed to the nature of environmental literacy, which utilizes discipline integration, problem solving and hands-on activities (Glynn, 2000).

Theoretical Framework: The study is underpinned by argumentation framework as espoused by Toulmin’s (1958) Argumentation Pattern (TAP) and Ogunniyi’s (1997) Contiguity Argumentation Theory (CAT). The two theories accord with Vygotsky’s notion of constructivism whereby an individual learns or acquires new experiences from his/her interactions with his/her physical or socio-cultural environment. The TAP construes learning in terms of the ability to support one’s claim with valid evidence or reason while the CAT construes learning as a product of self- or cross conversation and reflection. This study would explore the application of both TAP and CAT in the context of classroom discourse dealing with selected meteorological concepts. Toulmin (1958) also suggested that a substantive argument is to move data to a claim. Three elements make up the Toulmin’s basic model an argument, which is: C (claim) that represents the statement of the speaker, D (data): represents the data that justifies the claim of C, and the, W (warrant): who is the inference rule, which allows data to be connected to the claim.

Dialogical argumentation occurs when different perspectives expressed on a subject with the hope of reaching consensus in the end. The purpose is to persuade others of the validity of the claim through well-reasoned or well-grounded arguments rather than win a case. Through dialogical argumentation learners articulate their “reasons for supporting a particular claim and then strive to persuade or convince” (Ogunniyi 2008) others about the truthfulness of such a claim. Dialogical argumentation provides the critical “environment for learners to externalize their doubts, clear their misgivings or misconceptions, reflect on their own ideas and those of their peers in order to arrive at clearer and more robust understanding of a given topic than would have otherwise been the case” (Ogunniyi 2008).

This research study proposed a methodological tool: Toulmin's (1958) Argumentation Pattern model (TAP) with Ogunniyi’s (1997) Contiguity Argumentation Theory (CAT) to compare and analyse the understanding of grade 9 learners conceptions on selected meteorological concepts in education research. By using the dialogical argumentation based instruction is to proof the characteristics of classroom argumentation and its relation with meteorological concept understanding.

Literature Review: Research shows, that only if argumentation is specifically and explicitly addressed in the curriculum will students have the opportunity to explore its use in social science (Kuhn, 1991). Because science education mainly focuses on learners’ understanding of science concepts and adopting using different ways in achieving this, like transmission learning and not drawing on reasoning only the delivery of science facts. Using teaching methods that uses argumentation through the use of appropriate activities and teaching strategies in the social science class can provide a means of promoting a wider range of goals,
including social skills, reasoning skills and the skills required to construct argument using evidence (Osborne, Erduran, & Simon, 2004a). So, in order to emphasise that teachers need argumentation during teaching social science, they (teachers) need to adapt their teaching styles to a more dialogic approaches (Alexander, 2005) that will involve students in class and lesson discussions, and using teaching methods to interact with students to foster argumentation skills.

The use of Zone of Proximal Development (ZPD) and Scaffolding will contribute positively to construct valuable argumentation instructional patterns. Vygotsky (1978) used the term (mediator) to convey the role of the teacher who actively and thoughtfully mediates the culture (knowledge, skills and values) to learners in such a way as to enable them to appropriate the culture for themselves, assimilating it into their own systems of meaning, adapting it as they adapt those systems, and developing competence in the process.

According to Vygotsky (1978), ‘learning awakens a variety of internal developmental processes that are able to operate only when the child is interacting – with people in his environment and in co-operation with his peers’ (Vygotsky, 1978). The central notion of the Zone of Proximal Development (ZPD) refers to the gap between a learners’ actual level of development (what he/she can do on his/her own without assistance) and his/her simultaneous potential level of development (what he/she is able to do under adult guidance or in collaboration with more capable peers).

As stated earlier, this study is underpinned by an argumentation framework as espoused by Toulmin’s (1958) Argumentation Pattern (TAP) and Ogunniyi’s (1997) Contiguity Argumentation Theory (CAT). The two theoretical frameworks are chosen because of their amenability to classroom discourse dealing with phenomena on which learners might be holding conflicting worldviews. These frameworks provide the necessary context for inductive, deductive and analogical reasoning. They also accord with the Piagetian and Vygotskian notion of constructivism namely, that knowledge is constructed as one makes sense of the world around him/her. This type of reasoning can be use as an instructional tool to learners who constantly interacts with their environments and surroundings. Interacting with the environment and your surroundings great experience are gained where individuals relate to that the environment in a sensible and responsible manner.

While there are many places where learners can learn about environmental literacy, the most effective locations perhaps is the schools. The school plays a vital role in the process of helping children to acquire environmental literacy and awareness. School science classes are the contexts in which learners are exposed to activities, which enhance their knowledge and awareness of their environment. The CAT assumes that when different ideas interact they tend (through a sort of dialogical process) to find areas of commonality i.e. areas where their subsumed elements are compatible and this ultimately may result into a higher form of meaning than was previously possible (Ogunniyi, 2008).

Methodology: A survey will be conducted in 3 secondary schools in the Western Cape to explore learners’ ideas about meteorological concepts and attitudes towards their environment. This will be followed by implementing a Dialogical Argumentation Instructional Method (DAIM) to enhance learners’ understanding of selected meteorological concepts in one secondary schools in the Strand. The effectiveness or otherwise of the DAIM will be determined using an Meteorological Literacy Test (MLT), an open-ended questionnaire, a semi-structured interview and classroom observation schedule. The data
collected through the various instruments will be analyzed in terms of appropriate quantitative and qualitative descriptions.

The study is based on a case study design with two main components namely, a quasi-experimental design component and a qualitative research design component. The purpose of experimental research is describe “the consequences of a direct intervention into the status quo” (Ogunniyi, 1992:81).

The quantitative aspect of the study in form of quasi-experimental pre-test-post-test control group design is as shown below: Quasi-experimental Control Group Design

The research design can be both quantitative and qualitative in nature e.g.

\[
\begin{align*}
O_1 & \times O_2 \quad (\text{Experimental group}) = (E) \\
O_3 & \quad O_4 \quad (\text{Control or Comparison Group}) = (C) \\
O_1 & \times O_2 \quad = \text{Pre-observations} \\
O_3 & \quad O_4 \quad = \text{Post-observations}
\end{align*}
\]

**Figure 1:** Quasi-experimental control group design

\(O_1\) and \(O_2\) represents the pre-and post-test observations for the experimental group (E) whereas \(O_3\) and \(O_4\) stand for the pre-and post-test observations for the control group (C). \(X\) stands for the treatment, namely the dialogical instructional method. The dotted line indicates that intact rather than randomized groups were used (Ogunniyi, 1992:91).

The study will be conducted among two intact class groups from a public high school (called school “X” for now) in Strand. The school is situated in a socio-cultural and economic background area in the Helderberg Basin. The sampling will involve two grade 9 classes from the same school and participants will range from 14-16 years of age. Classes will be positively selected on basis of comparability with respect to: classes doing the same subject and taught by the same teacher, then based on formal class test and reports, and lastly based on the socio-cultural and economic backgrounds of the learners.

**Data Collection:** The data collection for the qualitative design consists of, (a) observation of the school culture within various departments such as, Geography department, Social Science Department and Life Science department, (b) observation of school and classroom environment, (c) learner and teacher view in relation to concepts dealing with meteorological literacy, and (d) other techniques such as; questionnaires, interviews, MLT-test, and observation schedules will add to the data collection process. Qualitative research methods will be used like: a questionnaire with open and close-ended questions, to be completed by the participants. Observations schedules visits to classroom while teaching take place, and focus group interviews with all participants. Quantitative research methods will be introduced in the form of a Meteorological Literacy (MLT)-test, consisting of questions and concepts dealing with meteorological literacy for learners. Data will then be analysed in terms of statistical correlation between the measured variables.
The treatment of all data will include two important aspects, (a) analysing, interpretation and completion of all data with a statistician and a computer program the SAS (Statistical Analysing System) and (b) that all findings and conclusions in the research is a main objective to answer the research questions. The findings would serve a dual purpose to (1) identify learners’ conceptions around meteorological instances and (2) gauge the effectiveness of dialogical argumentation as an instructional method in teaching meteorological concepts.

**Ethical Consideration:** For all ethical considerations the researcher will issue a research application letter to WCED (Western Cape Educational Department) to ask permission to perform the research study at the selected schools. A letter of consent will also need to be completed by the (SGB) School Governing Body’s informing them of the research process and obligations of the study were the survey and research will be conducted. All participating schools are entitled to a summary of the research study that was conducted for feature organizational and curriculum planning. All participating learners will also be informed of the implication of the study and how the data will be analysed and interpreted, and for which purpose. A Letter of consent needs to be signed by parents of all under-age participants in the research study. Also informing all students of their right and obligations within the research process.

**References**

Using drama to teach science: Exploring and occupying the ‘empty space’

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Sociocultural methods such as using drama have been promoted as productive ways for learning science. Specifically, role plays, using given roles or simulated and improvised enactments, are claimed to improve learning of concepts, understanding the nature of science and an appreciation of science’s relationship with society (Ødegaard, 2001). So far theorization of science drama has been lacking and no attempt has been made to integrate theory from science education with that of theatre. This paper draws on Peter Brook’s notion of the theatre as the ‘empty space’ (Brook, 1968) to provide a new model acting as a lens through which sets of drama activities used to teach science can be better understood and evaluated. Brook’s concept of the ‘empty space’ is seen as analogous to the cognitive space or degree of dissonance between the learner’s and scientist’s different worlds of knowing. This new theorisation for science drama helps science education return to the core intentions of a so-called ‘constructivist approach’, that have not been apparent in some other examples of teaching.

Introduction

A common view of teaching and learning science is that the science world of knowing conflicts with the learner’s world of knowing and thus some ‘construction’ or re-construction of what is in the learner’s head, rather than mere transmission of knowledge, is required. However, teaching methods have rarely provided ways of realising this ‘constructivist approach’, since traditional pedagogy involving transmissive modes, text-based learning and written tasks have dominated teaching (Tytler, 2007). Tytler calls for a wider view of learning taking account of research and scholarship in the sociocultural tradition, paying attention to the ways in which a teacher promotes methods in which groups of learners negotiate meaning in shared tasks. One group of methods in this tradition uses various forms of drama (enactment, role play, movement, mime and dance) to make ideas, theories and processes, at varying degrees of complexity and abstraction, more comprehensible to learners through their more active involvement in the reconstruction process. Additionally, drama in science models ways in which scientists develop and validate theories and provides a productive platform for debating the social, political and cultural dimensions of science that help give science a human face for pupils sceptical of its worth (Ødegaard, 2003). Drawing simultaneously from
two academic traditions, the arts and sciences, to teach science content may seem problematic and overly neo-liberalist, but there are sound reasons for doing this as will be shown in the discussion that follows. Both dramatist and scientist are fascinated with phenomena, that motivates them both to provide metaphoric and explanatory responses for these phenomena. As Fels and Meyer put it, ‘the question “what if?” prods scientist and dramatist towards creative exploration and interpretation of experiential, sensual worlds, real and imagined’ (Fels & Meyer, 1997:75). In this paper I show how theory in the traditions of science education and theatre can be brought together to rationalise and illuminate drama practiced in the science classroom.

Theoretical background

The need for a new theoretical perspective

As Ødegaard points out in her critical review of drama in science education, the words ‘theatre’ and ‘theory’ share common etymological roots in the Greek verb ‘theorein’: to see, view or behold (Ødegaard, 2003: 75). Thus science and drama concern a search for truth through universality and generalisation drawn from observational experience. Drama and science both seek explanations of the world through real, imagined or vicarious experience, but it is at the interfaces with their respective audiences (the theatre audience and school learners) that there are useful parallels to be drawn. Ødegaard goes on to point out that, in spite of its apparent usefulness to learning science, drama in science education is a field that is neither highly theorised or highly researched (Ødegaard, 2003:76). Theorisation has been hampered by historic, academic precedents. In the UK and other countries, education theory and development has been bedevilled by schisms, suspicions and petty jealousies between, what C.P. Snow called, ‘the two cultures’; one concerned with the arts and humanities the other with science. This unhelpful division is anachronistic and blocks innovative academic advancement limiting potential cross-contributions that one academic field can make to the other. Nobel laureate astrophysicist George Smoot sees the old divisions between the cultures of arts and sciences as dead. He points to a new, third culture more heavily dominated by science and technology of everyday life and the big events that impact globalisation, economics, politics and democracy in the 21st Century (see Braund, 2008:xii). So it is timely to build a sufficient and sophisticated theory of drama in science education, one that is equally helpful to the theorist and the practitioner and that ultimately assists the research and practitioner communities in evaluating what it is about drama tasks used in science teaching that brings about better learning of science content and for broader scientific literacy. To do this, and at the same time move away from the restricting two cultures paradigm, it is necessary to draw on three fields of scholarly endeavour; in science education, in theatre theory and in drama education. In this paper drama education is not discussed, only as a more minor part of theatre and science education, but that is not to say that it has a lesser history or quality – just that, to do it justice, is beyond the scope of this current paper. Drawing from theatre and science education and rationalising between them helps build a model for drama in science education as well as exploring, in a little more depth, some of the justifications made for drama in science and claims for its successes as a learning method.

A perspective from science education

Drama is most often included in lists of what educators refer to as ‘active approaches’ to learning (O’Loughlin, 2007). Active learning is a misleading term since it implies that less active modes of learning; reading text, listening to the expositions of a teacher, writing
answers on a worksheet, are somehow lower in intellectual engagement and mental stimulation and therefore less worthy, and of course this may be far from the case. By ‘active’ what is often meant is that the learner plays an integral, crucial part in the construction or reconstruction of knowledge, often by interaction with other learners and the teacher. In this way drama is part of what prominent science educators in the constructivist tradition had in mind as ‘discourse communities’ in classrooms aimed at establishment of shared meanings rather than assimilation through independent learning or by merely being told science content (Driver, et al, 2004). According to Wertsch (1991), this is part of a sociocultural approach to learning that has a fundamental role in the development of language and culture and even the way we think. Additionally, Aikenhead has taken the view that sociocultural learning, including enactment of ‘science storylines’, helps border crossings from indigenous ways of thinking to more scientific thought (Aikenhead, 2001, 2006).

Ødegaard sees drama contributing to three areas of learning in science education; about concepts, about the nature of science and science’s interactions with society. There is evidence that conceptual understanding is advanced through use of drama. Simulations to understand circuit electricity have been used with teacher education students and primary schools and improved understanding of current, voltage and resistance claimed (Tveita, 1998; Braund, 1999). In Biology, concepts in photosynthesis (Carlsson, 1992) and about cell division (Ødegaard, 2001) have been advanced. Improvement of learners’ ecological concepts, such as feeding interrelationships, has been claimed using role plays where learners act components of food chains and webs (Bailey, 1994). As far as educating about the nature of science is concerned, Ødegaard claims ‘stories of science’ such as those used by Aikenhead, mentioned earlier, offer learners new insights into the reality of the processes of scientific practice (Ødegaard, 2003:85). Solomon et al, (1992) see activities, such as plays about the history of science, challenging positivistic-empiricist views of science as they show how science theories have been developed and are open to challenge and re-construction. This was the case of Jill’s lesson described by Braund et al., where a series of radio interviews of space scientists through the ages was used to teach about the development of ideas towards the solar-centric model of the solar system (Braund et al., 2007). The use of drama in science has been promoted as improving learners’ empathy and identification in socio-political situations of science and even having capacity to challenge or change learners’ world views (Aikenhead, 1996; Ødegaard, 2001; Cobern, 1996). In England the ‘Y Touring Company’ has been hailed as a leader in using short plays to focus debate for learners about uses of biotechnology and bioethics. Gains included specific and marked shifts in learners’ attitudes (Evaluation Associates, 1998).

Before turning to theory in theatre, it is worth noting justifications used for arts education (including drama) helping develop general and specific (scientific) cognitive capacity. Justifications have commonly been made from the perspective of neurobiology. Since the mid 19th century there was increasing evidence, from studies of patients with brain impairments, that the left and right hemispheres of the cerebral cortex might be differentiated and hence control different physical and cognitive functions. Sperry’s Nobel prize winning research on patients with severed corpus callosum (the region between the two hemispheres) showed language ability was clearly associated with left hemisphere function and discrimination of shape and design with the right (Sperry, 1966). Drawing on Sperry’s work, Herrmann went on to postulate different abilities and types of thinking associated with the two hemispheres. Analytical and sequential reasoning was said to be associated with left brain function while the right side deals with interpersonal, imaginative and emotional thinking (Herrmann, 1990).
This led some to a rather unsophisticated, reductionist view that the arts are about the right side of the brain and science and mathematics the left. However many have challenged the location of, what Gardner (1983) later called ‘hypothetical-deductive reasoning’, in the left brain. An often quoted example is mathematically gifted children who tend to be left-handed and therefore have right hemisphere dominance (the right brain controls left side body movements). Reading about these linkages led drama educator Dorothy Heathcote to advocate drama activity as a way to strengthen scientific reasoning, as the right-brained activity could lead to a ‘left-handed way of knowing’, that is thus more ‘scientific’. (Wagner, 1979). Modern brain biology has challenged the ideas supporting separate brain functions and, in his very useful review of the field, Morris points out that most cognitive scientists and educators today favour a more ‘whole brain function view’, acknowledging that activities drawing on a wide a range of stimulation as possible inevitably improve brain function, especially for higher order activity and critical thinking (singsurf.org, 2010)

A perspective from theatre

In a series of lectures in 1968, renowned English director Peter Brook attacked the theatre of the time for its staid, traditional, classical approaches, lack of imagination and failure to attract and engage new audiences (Brook, 1968). In many ways his concerns echo those of science educators today in many countries who bemoan lack of enthusiasm of learners for science and a reducing likelihood of them choosing further study or science related careers (Millar & Osborne, 1998). Brook was the major theorist of his generation drawing on ideas of dramatists and writers such as Artaud, Brecht, Ibsen and Beckett to show how theatre could use more dynamic, visual, metaphorical and allegorical approaches drawn from traditions of Asian, African and Far Eastern theatre to occupy what he called the ‘empty space’ that he saw existing between audience and actor and/or director. His ideas revolutionised theatre for generations. Brook’s ideas have great resonance with science education and illuminate best ways in which it can use drama.

Brook termed the traditional, realist theatre of the mid 60’s the Deadly Theatre because he saw negative effects of the dead hand of commercialism in Europe and America, concerned more with audience returns and making money than artistic adventure and modernism. Even the more liberating theatre of Brecht and Beckett, let alone of Shakespeare, had been turned into staid and lacklustre events, no longer capable of transmitting the visions, stories and beliefs of the playwrights. For Brook, the director can never be passive, letting the play ‘speak for itself’, rather, he must ‘conjure its sound from it’ (Brook, 1968:43). In the Deadly Théâtre, repetition of the old mistakes abound as much in opera, musicals and ballet as they do in theatre; old formulae and methods, old jokes, stock beginnings and endings will no longer do (ibid, 44). For science education, one of Brook’s alternative visions of theatre, the Holy Théâtre, holds promise for closer study. This is theatre making the abstract and the invisible, visible. Here, Brook touches on Artaud’s notion of the play as an event transcending the text from which it is born. The language is of actions, sounds, images and movements but it is also about the words as parody, lies, contradictions and shocks. In Brook’s theatre the ‘empty space’ is filled by a much richer and enhanced experience, stimulating its audience by use of metaphor. I was lucky enough to experience this at first hand, seeing Brook’s Dream (Shakespeare’s, A Midsummer Night’s Dream) performed by the Royal Shakespeare Company in 1972. The stage was a white box, the forest a set of swings suspended from the ceiling. The play’s natural magic was added to by ethereal sounds created by plastic tubes,
whirled over their heads by the actors. None of this detracted from the text which took on new life and meaning. It remains the most thrilling and memorable performance of any play I have seen in 40 years. In such endeavours, Brook clearly draws on Artaud’s Theatre of the Absurd, but not in a literal or surrealist way. For Brook, the real value of Artaud is that he was using the unreal to expose a reality in the obscured truths of our everyday lives. Thus for Artaud the theatre becomes a place in which a greater reality could be found (Artaud, 1958).

In Brook’s second alternative vision of theatre, The Rough Theatre, performance is informal and ephemeral, often without a conventional stage or theatre (Brook, op. cit., 73-109). Here, content and acting take charge but informality does not imply mental sloppiness. Events engage audiences in real thought, the audience must make an intellectual effort. Here, Brook leans heavily on the theories of Bertolt Brecht, who used dramatic scenes in his plays to challenge what we might first perceive about a character’s intentions and the social and political situations in which they find themselves (Brecht, 1964). Thus in his play Galileo, perhaps the greatest benefit for an audience is to help them get away from a simplified understanding of the relationship between science and religion in which the two are always in conflict. The standard, some have argued ‘mythical’, version of the Galileo-Church interaction is that, as an old man Galileo was imprisoned and tortured by the Church for refusing to abandon his scientific conclusion that the Earth goes round the Sun rather than vice versa. We shouldn't, of course, see Brecht as presenting a neutral view of the issue but even if one ignores the circumstances in which the play was written (shortly before the outbreak of the Second World War while Brecht was in exile in Denmark), even a cursory attendance to the play serves to undermine the conflict model and helps an audience appreciate the historical contingencies. For an audience of science students, Brecht’s approach leads to new understandings about the nature of science and its relations to society both in Galileo’s time and in our own.

Brook’s final vision for theatre, The Immediate Theatre, proposes a powerful role affecting our very consciousness as human beings. Brook closes his final lecture by reminding us that in theatre truth is always on the move. In theatre, rather than any other art form, it is possible to wipe the slate clean. At every performance, new interpretations, emotions and, hence, outcomes for audiences are possible. The parallels with the written word or painting and sculpture are stark – these are interpretations of a moment forever frozen in time (op. cit., 156-7). Thus theatre is an experiment in interpretations of reality where questions of ‘what if?’ are explored rather than being evaded or fictionalised as half truths and lies as, often, in real life.

A model of drama in science education

The construction of a model for drama in science has two purposes. First to help draw together the two fields of theory, in science education and theatre and, second, to provide a means through which the use of drama activities in science teaching can be better understood and evaluated. For the purposes of the model, learning science is seen as a process rationalising two worlds of knowing, the learner’s world and the scientist’s. The learner’s world draws on everyday experience, commonly used terms and language and what has been gleaned from science as presented knowledge from media and from family, friends and school. The scientist’s world of knowing, which is the eventual target for learning change, has specific rational explanations for the world based on applications of concepts and theories
mediated by empirical validation. This view can be represented as a general model for learning science, Figure 1. In this general model ‘cognitive dissonance’ is the ‘distance’ between the two worlds of knowing and the ‘experiential space’ is the nature of activity and effort, used by the teacher, to reduce the amount of cognitive dissonance and so close the gap between the two worlds.

![Figure 1. A general model for learning science.](image)

In the second stage of model formulation, this general model is made specific to drama as one way of closing cognitive dissonance (see Figure 2). In the second model, Brook’s ‘empty space’ is seen as analogous to the experiential space, now the ‘drama space’. Though the ‘space’ is not empty in terms of learners’ existing ideas (neither is it for theatre audiences), the methods used by the teacher, their confidence and skill at using them and the learners’ efficacy (belief about learning value) and attitudes to drama as a learning method also populate the space and must be taken into account to ensure success of teaching approaches. It is here, that content design and teaching methods have much to learn from the ways in which Brook’s see theatre filling the empty space. It could be argued that the model could be used more widely than for drama – perhaps for many approaches in the sociocultural landscape of learning. The word ‘drama’ could be substituted with ‘practical work’, ‘group task’ and so on.

![Figure 2. A model of drama for science learning](image)
However, what makes drama special to consider using this model, and sometimes more demanding for teachers to use than other forms of learning in the ‘active’ tradition, are the particular pedagogical features and decisions that must be taken to get the most from any particular task and that are unique to different forms of drama task. As Dorion points out, from classroom studies of just one type - physical role plays, these events require complex analogies and continuous combinations of implicit and explicit anthropomorphism (Dorion, 2009: 2266). Other types of drama, using dance and movement or performed scripts, might also be improved by drawing on Brook’s notions of the Rough or Immediate theatres. Whatever type of drama used by teachers, there is inevitably going to be a question of the extent of ‘pedagogical border crossing’ required, from the pedagogy of drama to the pedagogy of science, to make drama useful as a tool for learning. For some teachers the border crossing is not so great, they feel comfortable with drama and methods used by dramatists and drama educators, for others the crossing is difficult or never made and this could be a question of how they see the nature of science and how it is best understood.

**Realising and exploring the model**

Logically, the next stage is logically to develop and test the model. A team of science and drama educators in England and Turkey have produced over forty activities covering the range of topics most often taught in physical and natural sciences to learners aged between 11 and 16 (Abrahams, Braund and Saglam, forthcoming). At this stage the development team is keen to explore the first three aspects in the model in Figure 2 that occupy the drama space, that is: the type of drama, the design of the task itself and the teacher’s confidence and skill at using the tasks. The guiding question here is, to what extent is each of these effective in closing cognitive dissonance between the idea in the world of knowing science and learners’ understanding of that idea? For example, in a simulation about predator and prey relationships in a forest, what aspects of the task, the ways the teacher carried it out and ways that learners engaged with and acted their roles help (or hinder) the formation of concepts about survival behaviour of birds? One problem already identified, is a tendency for some learners, as ‘actors’, to situate learning too literally in acted out roles, for example as molecules, cells, electrical components and so on, thereby generating drama-induced misconceptions of the science. To explore the tasks in this way the team are collecting extensive video, photographic, questionnaire and observation data. Through this the suitability of the model for explaining how drama activities work best at classroom level can be explored.

**References**


The international community looks towards Education for Sustainable Development (ESD) to address global problems such as environmental degradation, poverty and ill-health. This article focuses on the integration of ESD into science lessons. It reports Junior Secondary School (JSS) science teachers’ perceptions of the ESD concept; its integration into their teaching and what they perceive to be the role of traditional, cultural practices in promoting ESD through science teaching.

Semi-structured interviews were conducted with sixteen JSS teachers from a variety of school contexts. The data were analysed using the Grounded Theory methods. The findings reflected that the teachers were not familiar with the ESD concept. However, they claimed to be unknowingly practicing its integration in some of their teaching. The environmental aspect of ESD was perceived as most suitable for integration into science teaching. Specific cultural activities related to the science curriculum and ESD were seen as an avenue for encompassing the social aspect too.

Introduction

Like many developing countries, Swaziland is faced with problems of environmental degradation, poverty and ill-health, and the education system is expected to play a significant role in addressing these problems. The country’s first education policy aimed at cultivating an enlightened and participant citizenry, and also aimed to retain and strengthen Swazi cultural values. The current National Policy Statement still explicitly emphasises cultural development, socio-economic development and environmental awareness (Ministry of Education, 1998a). These goals seem to be in line with the United Nations’ emphasis on education for sustainable development (ESD). Accordingly, Swaziland has launched the United Nations Decade of Education for Sustainable Development (UNDESD) in 2006 and a national ESD strategy has been drafted (Ministry of Education, 2009).

Although Swaziland has a strong Environmental Education (EE) background, citizens seem to have a limited understanding of the ESD concept. Initiatives to extend EE into ESD have commenced: different education officers are trained and appointed, and two ESD workshops for a few teachers from various subjects were held.

According to the National Policy, the goals of the science education include changing learners’ attitudes towards the environment; inculcating an appreciation of indigenous heritage; and empowering learners to address social and economic issues using the scientific approach (Ministry of Education, 1998b). Therefore, science teachers may be expected to contribute to educating learners for sustainable development within the contextualized science
syllabus. Fullan (2007) claims that teachers’ beliefs strongly influence the implementation of curriculum innovations. Thus, it is necessary to establish science teachers’ views about ESD and about opportunities for integrating ESD in their teaching in order to inform curriculum change. This study addresses the following research questions:

1. How do JSS science teachers perceive ESD?
2. How do JSS science teachers view the integration of ESD in their teaching?
3. What do JSS science teachers consider to be the role of Swazi culture in teaching for sustainable development?

Literature Review

What is ESD?

Concerns have been expressed about the catastrophic human activities intending to bring about development, but giving rise to problems such as environmental degradation, poverty, diseases and social disintegration. It is believed that promoting sustainable development (SD) might result in curbing these challenges. The Brundtland Commission report defines sustainable development as “the development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987: 43).

Although the Brundtland definition is still widely accepted, the report’s disregard of indigenous knowledge as a means to achieving SD has been challenged (Breidlid, 2009). It is generally agreed (for instance, see Huckle, 2006; Webster, 2004) that SD comprises environmental, social and economic aspects. The relationships between these three components may be represented by any of the models shown in Figure 1.

![Figure 1. Models representing the three aspects of sustainable development](image-url)
The common depiction of overlapping circles as in Model A has been criticised for disregarding that the economy and society cannot develop independently from the environment (Webster, 2004). Instead, model B considers the environment as providing the boundaries for society, and society as determining the nature of the economy. The international community pointed to education as the most effective way of promoting sustainability. ‘Education for Sustainable Development’ emphasised people empowerment to address environmental and development issues by changing their attitudes to development and to bring about behaviour change, in addition to providing knowledge and skills (UNESCO, 2005).

**Why include ESD in science teaching?**

Science has been perceived as an abstract and irrelevant subject to most learners in school, and many learners feel alienated by science (Carter, 2008). However, motivation and interest might increase if school science is to include sustainability, thus promoting scientific literacy and social responsibility among learners, and equipping them with participatory skills to address local and global problems such as disease, environmental degradation, climate change and poverty (Kyle, 2006). Hodson (2003) cites several obstacles to the implementation of a more sustainability-friendly science as universities, scientists, parents, teachers and the learners themselves, who may have theory-focused expectations of what the curriculum should entail. He also acknowledges that measures for assessing learners in a sustainability-focused curriculum still need to be developed. Nevertheless, he argues for issues-based science teaching. According to Rauch (2002), learners’ own experiences in specific, life-centred situations should be used to teach sustainability issues. Kasanda et al. (2005) show that contextualisation promotes relevance, social confidence and empowers learners to be productive, benefiting both themselves and society. This seems to be the kind of science education required to empower learners to participate in addressing sustainability issues. However, Campbell et al. (2000) found that the majority of Swazi learners in their study could not use knowledge gained from learning through the contextualised approach to explain everyday social and economic issues. Furthermore, Lotz-Sisitka (2006) points out that despite the emphasis on context and culture in South African educational policy, practice is still quite different. This discrepancy is aggravated by the ignorance of learner aspirations for change, which thwarts the relevance of school science to their everyday life.

Western science has enjoyed monopoly in education over the past years without giving room to indigenous knowledge as it was considered non-scientific, inefficient and outdated (Breidlid, 2009). However, some cultural aspects need to be addressed for effective sustainable development (Vargas, 2000). Glasson et al. (2010) argue for the promotion of hybridised knowledge which merges world views from both the developed and developing world, since Western or indigenous knowledge on their own can’t achieve sustainable development (Breidlid, 2009).

This article reports Swazi science teachers’ perceptions of the ESD concept and their perceptions about its integration into their teaching of science using the current JSS syllabus, including their views on the role of indigenous knowledge systems in promoting ESD.

**Methods**

The sample comprised sixteen JSS science teachers, one per school, who had experience with teaching the whole JSS syllabus. The schools from all four regions of the country comprised urban, semi-urban and rural schools for access to a wide variety of cultural, social, economic and environmental contexts. Two of the teachers had previously been involved in ESD
workshops. After piloting with three sets of teachers, the semi-structured interview schedule was sent to participants prior to the interview to allow for proper collection of thought and to minimise tension that may be caused by teachers not knowing the basic content of the questions. Some teachers could not be reached by post and therefore the schedule was read to them over the telephone. Both English and vernacular were encouraged during the interview, and teachers could refer to either the syllabus or text books to exemplify topics under discussion. The interviews were tape recorded, and field notes were kept.

Data obtained were organised by open coding and themes (Glaser & Strauss, 2007) were drawn from the responses as required by the inductive grounded theory analysis method. However, for the perceptions of the ESD concept, a deductive approach was used in categorising responses into the three SD aspects.

**Findings**

The results are presented in three sections based on the research questions and the teachers are labelled A to P to maintain confidentiality.

**Perceptions of ESD**

More than half the sample said they were not familiar with the notion of ESD before the interview appointment. However, some of these collected information before the interview and presented spontaneous perceptions on ESD, along with those who had heard of ESD before. The description of ESD according to the Brundtland definition was presented to those that could not provide spontaneous views to enable them to engage in the discussion. These then provided interpreted views of ESD. Both spontaneous and interpreted perceptions were analysed deductively by categorising them into the three ESD aspects, as presented in Table 1.

**Table 1. Perceptions of ESD**

<table>
<thead>
<tr>
<th>Emphasized ESD aspect and theme</th>
<th>Spontaneous responses (n=9)</th>
<th>Interpreted responses (n=6)</th>
<th>No response (n=1)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Environmental:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Resource non-depletion</td>
<td>L*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Social:</td>
<td></td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>a. Critical thinking</td>
<td>K*, D*, H*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Maintenance of culture</td>
<td>M*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Socially responsible behaviour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Economic:</td>
<td></td>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>a. Self-reliance</td>
<td>K*, F*, I*, M*</td>
<td>A*, B*, N*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unclassifiable</td>
<td>C*</td>
<td>G*</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

*– heard of ESD before appointment;  o – unfamiliar with ESD before appointment
Table 1 indicates that all three aspects transpired from the teachers’ perceptions, roughly in equal frequency. Only teachers K and M - who had been involved in ESD workshops previously - presented a holistic perception of ESD. Apart from D who covered environmental and social aspects, all other teachers focused on only one of the three aspects, even those who had been provided with the Brundtland definition. Teacher E’s statement is representative of the perception biased towards the environmental aspect:

It [ESD] is to educate students, so that they can be aware when using the available resources, they use them in such a way that it does not have a detrimental effect to nature and the environment.

In his holistic statement, teacher K seemed to perceive the environmental aspect as encompassing the other two when he stated that:

The environment is (important) ... I’m not saying these others have not been considered, but it’s like they are down there like a shadow. When they (people) see a shadow they won’t say they have seen the person, and when they see the person they will not talk about the shadow and yet the shadow is also there.

This metaphor seems to reflect Webster’s (2004) concentric model of the relationship between the three ESD aspects.

The themes that emerged from spontaneous views include: conservation and resource non-depletion for the environmental aspect; self reliance for the economic; and critical thinking and socially responsible behaviour for the social aspect. A third theme was added to the social aspect (maintaining cultural values) in the interpreted views.

Perceptions on the integration of ESD into the science curriculum

All teachers regarded the science curriculum as suitable for integrating ESD. The following three themes emerged from the perceived purposes of integration:

1. To raise awareness of environmental issues.
2. To empower learners to practically take action in addressing sustainability issues.
3. To develop the individual and the community both economically and socially.

A representative statement of the teachers focusing on awareness-raising was presented by E when she stated that “by introducing it into the school curriculum people may be aware of what it is that leads to such things as global warming”. Raising awareness usually concerns the provision of factual information and understanding. In contrast, teacher I believed that ESD should be integrated to cultivate specific action among learners to bring about change:

If ESD could be infused into schools it would empower the children to go out there... they’ll be able to address these problems because these need to be addressed. And the people who are there are old. They just go to conferences e.g. on global warming and come back – so what?

Socially responsible behaviour overlaps with empowerment for action. For example, J suggested that the ESD may result in learners “educating other community members who are not exposed to sustainability lessons”.

Perceptions on opportunities for integrating ESD in the science curriculum

The criteria for deciding ESD aspects that are most suitable for integration in science seemed to be based on the associated science content. All but one teacher regarded the environmental aspect

140
aspect as most suitable for integration. Half the sample suggested that the social and economic aspect may be integrated occasionally, but for instance teacher N suggested that the subject history would be a better host. Teachers G, P and L regarded the economic aspect not suitable for integration in science teaching, and referred this to commerce or accounting.

Many teachers considered themselves already integrating ESD into their lessons, “but I was doing it indirectly, not knowing that I’m doing it” (G). Conversely, most of the teachers seemed doubtful of the extent to which they integrated it. Teacher L claimed that the syllabus is not explicit enough to enable teachers to integrate the full notion of ESD into their lessons. He argued that: “We have some of the topics in our syllabus that somehow touch on it. We may not spend that much time on it. It’s not so elaborate in the syllabus, but we do have it”.

Table 2 shows ten syllabus topics perceived as ESD-friendly by the teachers.

Table 2. JSS science topics perceived to promote SD

<table>
<thead>
<tr>
<th>Biology</th>
<th>Chemistry</th>
<th>Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecology (conservation, pollution, recycling, invasive plants, pesticides)</td>
<td>Wealth from the ground (metals and water)</td>
<td>Electricity (sources, power)</td>
</tr>
<tr>
<td>Healthy living (nutrition, diseases, drug abuse, posture)</td>
<td>Separating mixtures</td>
<td>Energy (including fuels and heat transfer)</td>
</tr>
<tr>
<td>Reproduction (teenage pregnancy, HIV/AIDS, STIs)</td>
<td>Kinetic particle theory</td>
<td></td>
</tr>
<tr>
<td>Renewable and non-renewable resources</td>
<td>Acids and bases (pH measurement)</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 indicates that three of the topics were biology, four were chemistry, two were physics and one cut across all three sciences. However, the last three of the chemistry topics were purely emphasising the need for relating them to the learners’ context and could not be extended to incorporate sustainability issues. This renders biology as the perceived dominant science in ESD.

Some teachers’ negative attitudes towards the currently implemented contextualised approach to science teaching was cited as a possible indication that they might also resist ESD integration. This emerged from teacher D as follows:

We do have challenges even now. We are trying to teach Science in Everyday Life (contextualised science text book) and there are people who are against it, saying this has made science very cheap. It is no longer the science that they were learning a long time ago.
Although some teachers admitted their limited knowledge of traditional cultural practices, sixteen practices emerged, related to nine science topics. Only five of these topics were relevant to ESD as the others focused only on contextualisation. One of the five topics (efficient use of resources) was not in the syllabus but was included due to its emphasis on the economic aspect while overlapping with conservation. Figure 2 relates the cultural practices to the five relevant topics and the three SD aspects.

Figure 2 indicates that all the practices were linked to biology topics, mostly focusing on reproduction and conservation. Three of the culture-related topics were categorised under the social aspect, with one under the environmental and one under the economic aspect.
Figure 2. Relationship between SD aspects, the cultural activities and the science topics
Discussion and Conclusion

More than half the sample indicated a lack of familiarity with the ESD concept. Even after an explanation of the term, the teachers held a fractured interpretation of ESD focusing on one of its three aspects only. However, in contrast with findings from industrialised nations (e.g. Bonnett, 2006) similar numbers of teachers associate SD with each one of the three aspects, not mainly with environmental protection. The identified notions of social responsible behaviour, maintenance of cultural values and economic self-reliance may form the stepping stones for building a holistic understanding of ESD. Generally, the teachers supported the integration of ESD into the science curriculum and the purposes for this varied from raising awareness; empowering for action and for socio-economic development of both individuals and the community. As Ansell (2006) found in Lesotho, some teachers attributed change to provision of knowledge and understanding, what Pitt and Lubben (2009) called teaching about SD. The perception of empowering for action indicates that others regard ESD as a means of prompting action to address individuals’ and community problems, thus teaching for SD. Coupling the latter with the purpose of socio-economic development of both the individual and his/her community may result in social responsibly school science (Hodson, 2003; Kyle, 2006).

When deciding on the suitability of integrating ESD in the curriculum, teachers used the match with current content as the main criterion. ESD was not seen as a potential cross-curriculum theme (see Huckle, 2006) such as HIV/AIDS education. Thus integration of ESD as seen by most teachers as apportioned to different subject. The current science curriculum was considered to be most compatible with the environmental aspect of ESD. Although some claimed that there was room to include the other two aspects, the majority saw no room for the economic aspect in science lessons. Instead, it was suggested that the other two aspects should be integrated into subjects with compatible content such as accounting or history. This seems to be in line with the proposed inter-disciplinarity of ESD (UNESCO/UNEP, 1977).

Teachers’ identification of ESD-friendly syllabus topics and cultural practices revealed confusion between ESD and contextualisation. Contextualisation is necessary for successful ESD, whereas it is possible to contextualise science teaching without expanding to embrace ESD. Equally, possible teachers’ negative attitudes to ESD might be based on their alleged negative attitudes to the currently implemented contextualisation of the science curriculum. Hence there might be a need to first strive for teachers’ acceptance of contextualisation before advocating acceptance of ESD.

Like the ESD-friendly topics, the cultural practices perceived to be linked to SD were biased towards biology and most of these were related to the social (reproduction) and the environmental (conservation) aspect; with only one linked to the economic aspect. This could signify the possibility that the cultural practices may be used as a vehicle for integrating the social aspect into science teaching, as much as the environmental one.

References


Exploring teachers’ and learners’ understandings of nature of scientific inquiry (NOSI): the validation of research instruments

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The paper discusses the adaptation and validation of one research instrument, on understanding of the nature of scientific inquiry (NOSI). The instrument is based on five general but interrelated constructs on science inquiry that also provide the conceptual framework guiding the study. The instrument aims to solicit information on interactions among learners’ understandings of the NOSI and teachers’ understandings of the NOSI. Preliminary findings from the instrument, the Learners’ Understanding of Science and Scientific Inquiry (LUSSI) are discussed. It was found that learners demonstrated the most confusions and misunderstandings in the laws versus theories aspect of NOSI. A number of learners demonstrated transitional views that were a combination of both naïve and informed understandings in the other five aspects of NOSI.

Introduction
The development of teachers’ and learners’ understandings of science and the nature of scientific inquiry (NOSI) is an important science education curriculum goal (Schwartz, Lederman & Lederman, 2008). The assessment of teachers’ and learners’ understandings of NOSI is currently, of interest to many researchers in science education (see, Lederman, 2007; Vhurumuku, 2009; 2010). Science education researchers have also been investigating learner perceptions of the levels of inquiry in science classrooms (see, Campbell, Abd-Hamid and Chapman, 2010; Taylor and Maor, 2000). This paper is based on a study which investigates interactions among teachers’ understandings of the nature of scientific inquiry (NOSI), teacher instructional practices, and learners’ understandings of the nature of scientific inquiry. These interactions are studied within the context of teaching and learning of scientific investigations at Grade 11 level in five schools in and around Gauteng, South Africa. Scientific investigations are part of what is referred to as inquiry in school science education. In this paper, I discuss the adaptation and validation of one of the research instruments used to assess learners’ NOSI understandings in science classrooms. Though three instruments, two on understandings of NOSI and one on learners’ perceptions of levels of inquiry were piloted, only one is discussed together with its preliminary findings.

Several instruments for assessing teachers’ and learners’ understandings of the NOSI have been developed and used. Among them are: Learners’ Understanding of Science and Scientific Inquiry (LUSSI) by Liang et al. (2006); the Views of Nature of Science (VNOS) by Lederman and Lederman (2006); Views of Scientific Inquiry (VOSI) by Schwartz (2007); Children’s Views of Science (CVS) by Lederman and Lederman, (2005); and Views of Scientific Inquiry (VOSI-Sci) by Schwartz (2004). To assess learners’ NOSI understandings, probes have also been used (see, for example, Ibrahim, Buffler & Lubben, 2009; Lederman, 2008). For the main study, the Learners’ Understanding of Science and Scientific Inquiry (LUSSI) by Liang et al. (2006) and probes as used by, Ibrahim, Buffler and Lubben (2009) are combined with interviews to assess learners’ NOSI understandings. For this paper the development and validation of interviews is not included. Focus is only on the LUSSI. The LUSSI has been chosen because it has been used successfully in contexts similar to South Africa and also because the data obtained is easy to analyze and prone to statistical analysis.
Conceptual Framework

This study is framed and guided by five (5) interrelated constructs on science inquiry which encompasses: the nature of inquiry in general; inquiry as practice of science; inquiry, the NOS and NOSI; inquiry as learning; and inquiry as teaching. These five general but interrelated constructs provide the theoretical framework guiding the study. The construct which has bearing on the LUSSI instrument is inquiry, the NOS and NOSI.

Inquiry, the NOS and NOSI. Traditionally, the concepts NOS and NOSI have been conflated (see Lederman, 1992). In this study, the NOS refers to an individuals’ ideas, beliefs, views, perceptions and assumptions about scientific knowledge – the facts, principles, laws and theories making the body of knowledge called science (Vhurumuku & Mokeleche, 2009). In this instance the term “nature of science” is reserved to refer to an individual’s views, ideas, beliefs, assumptions and values about scientific knowledge only (Schwartz, Lederman & Lederman, 2008; Lederman & Lederman, 2005). For example to believe that scientific knowledge does not change is to harbour an idea about NOS. The same would be true for subscribing to the ideas that scientific knowledge is absolutely true and that it is totally objective. Schwartz, Lederman and Crawford (2004) have referred to the ideas, views, beliefs, assumptions and values which people have about the activities and practices of scientists as Views of the Nature of Scientific Inquiry (VNOSI). As already noted, scientific inquiry involves investigative processes including problem formulation, hypothesizing, questioning, predicting, observing, collecting data, constructing meaning, explaining, reflecting and comparison of information with other sources. In this study the term NOSI shall be used as referring to the ideas, beliefs, views, perceptions and assumptions about the nature of scientific inquiry, harboured by an individual. This is taken to include an individuals’ ideas about the scientific process and enterprise. What constitutes understandings of NOSI are not the abilities or skills to perform investigations (to do), but rather the beliefs, views, perceptions and assumptions attached to the activities by the individual.

While a distinction is made here between NOS and NOSI, it is important to note that in the literature (see for example, Bell, Lederman, & Abd-El-Khalick, 2000; Matkins & Bell; 2001; Buffler & Laugksch, 2004; Clough, & Olson; 2004) this distinction fails to be that clear cut especially when the issue of what would constitute the tenets of each of these constructs is considered. For the NOS and the NOSI, tenets, are the ideas, principles, opinions or doctrines about scientific knowledge and the scientific process that are generally believed or held to be true by members of the science education community. The surveyed literature (e.g. Bell, Lederman, & Abd-El-Khalick, 2000; Matkins & Bell; 2001; Buffler & Laugksch, 2004; Clough, & Olson; 2004) reveals that some tenets have been categorized as belonging to both the NOS and the NOSI. McComas and Olson (1998) have identified 14 tenets of nature of science. From this list, six tenets have been chosen for exploration in the current study. Suffice to mention that there is an overlap of these tenets between belonging to NOS and NOSI. These tenets are: (1) laws and theories serve different roles in science; (2) observations are theory-laden; (3) scientists use a variety of methods to conduct scientific investigations; (4) scientists require accurate record keeping, peer review and replicability; (5) scientific knowledge is socially and culturally embedded; and (6) scientific knowledge is partly the product of human creativity and imagination.

These tenets are chosen mainly because of their relevance to the South African Physical Science curriculum. The tenets were also chosen because they convey the ideas that teachers are expected to develop from the teaching of scientific investigations and development of learners’ NOSI understandings at Grade 11 level. According to Clough (2007) these tenets can provide an acceptable level of generality regarding the NOS and NOSI that could be accessible for a level such as Grade 11.
This is the Grade level chosen for the current study. Furthermore, the elements carried by these tenets are consistent with current philosophical views of science and useful for combating students' naive views of scientific inquiry. As already noted, the NOS is about the knowledge itself and NOSI is about the nature of the scientific process. Thus, when one says, “scientific knowledge is empirically based” it might not be clear whether one is referring to the knowledge itself or the process by which it is developed and validated. This is an ambiguity appearing in the literature. Part of the challenge of this study is to bring about order and conceptual clarity regarding which tenets belong to NOS and which ones belong to NOSI. The surveyed literature appears to be vague on this issue (Hipkins, Barker & Bolstad, 2005; Rudolph, 2003; Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; Smith, Maclin, Houghton & Hennessey, 2000; Lederman & Neiss, 1997).

Research questions
The question which the instruments are addressing is:

1. How do learners’ understandings of the NOSI relate to their teachers’ understandings of the nature of scientific inquiry and teacher instructional practices?

To help understand and elucidate the above question, two sub-questions are asked:

1. What are learners’ understandings of the nature of scientific inquiry?
2. What are teachers’ understandings of the nature of scientific inquiry?

This paper describes the validation of one research instrument used to investigate learners’ understandings of the nature of scientific inquiry.

Learners’ Understanding of Science and Scientific Inquiry (LUSSI)
The Learners’ Understanding of Science and Scientific Inquiry (LUSSI) instrument was adapted and modified from Liang et al. (2006). It blends Likert-type items and related open-ended questions to assess learners’ understanding of selected NOSI tenets. The six NOSI tenets chosen for this study are covered by this instrument. The original version of the LUSSI instrument comes from a combination of two instruments the VOSTS (Aikenhead & Ryan, 1992), and VNOS- Form C (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). Known as the SUSSI, the first draft of this instrument was developed by Liang et al. (2006) in 2004. The Student Understanding of Science and Scientific Inquiry (SUSSI) instrument has been globally tagged as a valid and meaningful instrument which has been used as either a summative or formative assessment tool in small and/or large scale studies and used to track learners’ growth and promote evidence-based practice in the learning and teaching of science (Liang, Chen, Chen, Kaya, Adams, Macklin & Ebenezer, 2008). The fully developed instrument has at least been face and content validated elsewhere in several countries including the USA, Taiwan, Turkey and China. The second version of the instrument was further examined for validity and reliability in three of the aforementioned countries (Liang et al, 2006). This study will be the first time that this instrument is used in Africa. Essentially, the instrument comprises a questionnaire in two parts which includes closed and open-ended questions. For each NOSI tenet, the close ended part asks learners to indicate their views on a five point Likert scale ranging from strongly agree to strongly disagree, similar to the instrument developed by Pemey (1993). The learners are then required to explain their views in the open-ended part of the question. The data from this questionnaire is intended to answer research question 3 of the main study.

Administration
Two schools located in and around Johannesburg (within 50km radius) in the Gauteng Province of South Africa were selected for their proximity and accessibility to the researcher for piloting the instruments. The schools are not part of the main sample of the study and are more or less generally uniform in terms of availability of teaching and learning resources for Physical Science and class sizes.
Two Physical Science Grade 11 teachers (n=2) and their learners (n=88) were used to validate the instruments.

Analysis
Partial preliminary results only from the LUSSI instrument are discussed in this paper. To analyze Likert items, a taxonomy of views about the nature of scientific inquiry was created based on the existing literature (see table 3, Appendix A). All 24 Likert items were classified into two groups: positive items or negative items. The statements marked as ‘+’ represented informed views consistent with the current National and International Science Education Reform documents, whereas the items with ‘—’ signs represented common learner naïve understandings of NOSI that are not consistent with the Standards documents (Liang et al., 2006). For each of the ‘positive’ Likert items, learner responses were assigned with numbers ranging from one to five (from ‘strongly disagree = 1’ to ‘strongly agree = 5’). The scores were assigned in a reversed order for each ‘negative’ Likert item. Mean scores for each component and the overall LUSSI instrument were calculated. Learner open-ended responses were scored using the SUSSI rubric provided by Liang (personal communication), categorizing responses as informed (score of 3), transitional (2), naïve (1), or not classifiable (0) as developed by Liang et al. (2009).

Results
The table below (table 1) gives percentage responses for each item under each tenet.

Table 1: Likert Item Responses

<table>
<thead>
<tr>
<th>Tenet</th>
<th>Item</th>
<th>Informed views (%)</th>
<th>Naïve views (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>81</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>22</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>30</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>84</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>7</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>8</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>5</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>46</td>
<td>22</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>78</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>86</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>68</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>38</td>
<td>23</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>49</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>38</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>33</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>50</td>
<td>27</td>
</tr>
<tr>
<td>Tenet 5</td>
<td>Item A</td>
<td>59</td>
<td>25</td>
</tr>
<tr>
<td>---------</td>
<td>--------</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>Item B</td>
<td>45</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>Item C</td>
<td>38</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Item D</td>
<td>42</td>
<td>32</td>
</tr>
<tr>
<td>Tenet 6</td>
<td>Item A</td>
<td>72</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Item B</td>
<td>31</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Item C</td>
<td>17</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Item D</td>
<td>66</td>
<td>9</td>
</tr>
</tbody>
</table>

Quite a number of learners demonstrated transitional views that were a combination of both naïve and informed understandings regarding the observations and inferences NOSI aspect. For instance, when individual Likert items within this aspect were examined, while 84% believed scientists would make different interpretations or inferences based on the same observations there was considerable portion of the learners (44%) who naively believed that scientists would make the same observations because they were objective and a significant portion 57% believed observations were facts. Within the subscale of scientific laws and theories, 46% participants agreed scientific theories explain scientific laws. With regard to the third tenet - change of theories, the overwhelming majority (86%) agreed that scientific theories may be completely replaced by new theories in light of new evidence. In response to the Likert statements fewer learners (1%) believed that scientific theories may be completely replaced by new theories in light of new evidence. Less than 23% participants demonstrated complete naïve views on the tentative nature of scientific theories. The social and cultural influence on science is the fourth NOSI tenet and fewer participants (27%) believed that all cultures conduct scientific research the same way and that scientists are trained to conduct pure and unbiased studies (36%). Though the number of learners demonstrated complete naïve responses (35-39%) which is slightly low, the number of learners with informed views was not high either (33-38%) across the sub-scale.

Analysis of individual Likert items regarding imagination and creativity in scientific investigations, the fifth NOSI tenet revealed that 45% of the participants believed that scientists use their imagination and creativity when they collect data and scientists use their imagination and creativity when they analyse and interpret data (45%). A few believed scientists do not use their imagination and creativity because these conflict with their logical reasoning (30%) and imagination as well as creativity can interfere with scientists’ objectivity (32%). The sixth NOSI tenet is the methodology of scientific investigations. Analysis of individual Likert items from this aspect revealed that 50% of the learners believed that there is a single, universal step-by-step method that all scientists follow and when scientists use the scientific method correctly, their results are true and accurate (51%). The percentages were then transformed into a bar graph (see figure 1 below) for clarity purposes.
From figure 1 above, it can be seen that participants demonstrated the most confusions and misunderstandings in the scientific laws versus theories NOSI aspect. With the other five tenets, participants seemed to harbor comparable informed views compared to naïve views. Table 2 below shows learner views categorized as informed views, transitional views, naïve views and/or not classifiable views from their open-ended responses.

Table 2: Open-Ended Responses

<table>
<thead>
<tr>
<th>Tenet</th>
<th>View</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tenet 1</td>
<td>Informed</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Transitional</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Naive</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Not Classifiable</td>
<td>0</td>
</tr>
<tr>
<td>Tenet 2</td>
<td>Informed</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Transitional</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Naive</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>Not Classifiable</td>
<td>5</td>
</tr>
<tr>
<td>Tenet 3</td>
<td>Informed</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Transitional</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>Naive</td>
<td>19</td>
</tr>
</tbody>
</table>
When constructed responses were examined, for the observation and inference NOSI aspect the percentage of informed views was found to be 38% whereas 30% of the learners demonstrated naïve views and 33% demonstrated transitional views. Constructed responses for the scientific laws and theories NOSI aspect revealed that 13% demonstrated of the participants had informed views while 43% were found to harbour naïve views with 30% of the learners demonstrating transitional views. Many respondents who agreed with the statement of “theories explain laws” also stated that “theories eventually become laws” showing little evidence of learner understanding of the difference between theories and laws. This was confirmed by follow up interviews. Interviewed learners believed unlike theories, scientific laws are not subject to change. Analysis of constructed responses showed fewer learners (8%) demonstrated informed views regarding the change of theories NOSI aspect. These learners (8%) gave the Atomic theory and Steven Hawkins theory as examples of theories that changed as a result of reinterpretation of existing data or observations.

Few learners demonstrated informed views (18%) with regard to social and cultural influence on science NOSI tenet whereas a low percentage was found to harbour naïve views (25%). The percentage of learners who demonstrated transitional views (25%) was also fairly low since most of the learners believed culture and society determines what or how science is conducted, or accepted and referred to the rejection of human cloning by several cultures. Percentages of both ‘informed’ views (24%) and ‘naïve’ views (22%) were lower than both ‘informed’ and ‘naïve’ Likert responses when focusing on the aspect looking at imagination and creativity in scientific investigations. When looking at the methodology of scientific investigations per se, a significant percentage of learners’ harboured informed views (34%) and were aware of more valid different scientific methods and techniques used by scientists, for example, experimentation, observation and so forth and the learners said these are used depending on the type of problem or question scientists are investigating. A low percentage were found to hold naïve views (27%) while an even very low percentage demonstrated transitional views.

For easier comparison and clarity purposes, the percentages were transformed into a bar graph (see...
Learner views from open-ended responses are graphically represented on figure 2 above. Tenet 2 on scientific laws versus theories depicts the NOSI aspect where learners demonstrated the most confusions and misunderstandings. Learners harboured transitional views mostly on Tenet 3 which deals with the tentativeness of scientific theories. Tenet 4 whose focus is on the social and cultural influence on science was the one with highest responses which could not be classified followed by tenets 5 and 6 on imagination and creativity in scientific investigations as well as methodology of scientific investigations respectively.

Discussion
Preliminary results from this study provide evidence that the sampled learners harbour NOSI views that range from naïve to somewhat informed views in both the Likert and open-ended response data from the six selected aspects of the LUSSI instrument. Learners’ responses to the Likert and the open ended questions were very consistent in most aspects although the percentage of informed views in the constructed responses was lower than the ones indicated in the corresponding Likert portion. Such discrepancy is explained by the fact that most learners discussed only interpretations and not observations for tenet 1 yet the scoring guide required learners to address both observations and interpretation to be rated as ‘informed’ hence a significant percentage were classified as having transitional views. In the same vein, the scoring guide talks of using imagination and creativity during all phases of scientific investigations for tenet 5 yet the learners where not specifying during what phases of scientific investigation hence their responses were also classified as transitional views.
Specifically, the participants appeared to be more informed about the tentativeness and durability of scientific knowledge. The history of science reveals both evolutionary and revolutionary changes regarding scientific knowledge. Participants realized that scientific theories may be abandoned or modified in light of new evidence or re-conceptualization of prior evidence and knowledge. Many learner participants were able to demonstrate their understanding of change of theories by providing valid examples, for example, by making reference to the Atomic theory. These findings are consistent with previous work by Liang et al. (2008) with Chinese teacher candidates.

Overall participants showed confusion and misunderstanding regarding scientific laws and theories. Learner participants gave good examples of laws and theories. The majority stated laws are proven hence will never change but theories are not proven hence change. A number of learners also believed theories develop into laws. The confusion seems to have arisen from the conception of the wrong definition of a “theory” which learners elicited during interviewing. Learners could not figure out that scientific theories are well-substantiated explanations of some aspect of the natural world. Theories do not become laws even with additional evidence. Theories just explain laws. This same confusion was shown by learners when responding to issues related to the observation and inference NOSI aspects. Learners believed observations of the same event should be the same and inferences should differ. What learner participants failed to realize is that the act of observation is selective, and one’s selection depends on who he/she is and one’s history, including what one already knows and what one expects and/or wants to find out. Therefore, it is not possible to eliminate bias completely as a result of scientists’ prior ideas. As human beings, scientists are influenced by subjectivity. Though most scientists strive to be as objective as possible, they are still human and will always be subjective to a degree.

Interestingly, participants believed scientists are inherently biased and so they can come to different inferences or conclusions based on the same set of observations or data. Findings are consistent with results from a previous study by Miller, Montplaisir, Offerdahl, Cheng and Ketterling (2010) of American undergraduate science and non-science majors.

Conclusion
Validity is about gathering evidence that can support the correctness and appropriateness of interpretations and inferences that can be made from the responses to an assessment instrument (Moskal & Leydens 2000). These preliminary results provide evidence that the sampled learners harbour NOSI views that range from naive to somewhat informed views in both the Likert and open-ended response data from the six selected aspects of the LUSSI instrument. In terms of face validity, content validity and construct validity, the instrument has passed the test and can be used in the main study. The work is significant in that it invites further thought about how NOSI views can be measured in larger populations. It also provides insight into the complexity and challenges involved in measuring and interpreting learner NOSI views. Other instruments like the LPCI, probes, teacher and learner interviews as well as classroom observations are used in the study to help assess whether teachers are able to translate their understanding of NOSI into learning opportunities for learners.

A Final Word
No tests of statistical significance have to date been performed.

References
Abd-El-Khalick, F., & Lederman, N. G. (2000a). Improving science teachers’ conceptions of nature of


Challenges in conducting research into the effects of an argumentation-based instruction on grade 10 learners’ understanding of the causes of pollution at a river site

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ABSTRACT
In this study I looked at the impact of argumentation-based instruction (ABI) on learners’ understanding the concepts of water pollution. Some challenges of ABI that I was acutely aware of, and that research has pointed to were; (i) time constraints; (ii) difficulties in managing discussion and (iii) teachers’ skills and views of science. Using a water pollution achievement test, the learners’ conceptions of water pollution were assessed before and after the treatment. A focus group interview was conducted after the post-test. ABI enhanced learners’ performances and they were very excited and enthusiastic about the teaching strategy.

INTRODUCTION
News media reports of the deaths of over 900 people of Haiti due to cholera, has highlighted the need for clean pollutant free water to all living organisms. This emphasizes the crucial role that educating communities about the effects of water pollution could play.

It seems as if education is failing a large part of its population. In spite of numerous efforts to improve results in high schools learners are apathetic towards science education in particular. They are still struggling to fully comprehend and assimilate the curriculum content. The traditional method of ‘talk and chalk’ permeates every lesson. The current educational system does not provide the expected matriculation results, especially in the former DET (Department of Education and Training) and HOR (House of Representatives) schools. In fact we find that from Grade 1 – 12 learners experience learning difficulties. Mathematics and science seem to be a major obstacle in learners’ performance. They are viewed as empty boxes that need to be filled and consequently the transmission method is still preferred by many teachers. It could also be that teachers cling to this traditional teaching method, because of a lack of training that should have been organized by the Department of Education (DOE) and perhaps due to teachers’ apathy.

This paper proposes an investigation into the use of dialogical argumentation as espoused by Toulmin (1958) as an instructional model for understanding pollution at a river site nearby a high school in the Western Cape, South Africa. The newly democratic South Africa opted for an Outcomes Based Education System (OBE, 1997), replacing the outdated segregating Christian National Education Policy (CNE). A new policy means new teaching strategies. Curriculum 2005 (C2005) proposes the teaching of science that recognises the importance of indigenous knowledge. Ogunniyi (2007) states ‘IKS reflects the wisdom about the environment developed over the centuries by the inhabitants of South Africa’.

In spite of all the vociferous objections to the new curriculum it has become a reality and every effort to make it succeed is required. Historically science has been seen as a body of unequivocal and uncontested knowledge (Simon, S. et al., 2006). C2005 suggests constructing dialogical argumentation in classroom discussions as critical aspects of school science and the development of process skills. It is clear from research that a curriculum that encourages discussion, argumentation, dialogue, and reflection is more effective for promoting understanding of the Nature of Science (NOS), IKS, or both (Erduran, Simon, & Osborne, 2004; Ogunniyi 2004; Simon et al., 2006). Kuhn (1991) argues that argumentation does not come naturally and that it is acquired through practice, it must be taught. It was my intention to research the effect of argumentation-based instruction on grade ten learners’ understanding of the causes of pollution at a river site. The current teaching method excludes learners’ participation whereas argumentation values their contribution. They become lively participants. Researchers’ who have tried to determine the effect of argumentation, preferred using Toulmin’s Argumentation Pattern (TAP) as an instructional tool and as a way to analyse learners and teachers understanding of the nature of science. Various theories underpin this study such as social constructivism.
(learning through interacting with others), TAP- instructional model to include the learner in the learning process and Contiguity Argumentation Theory (CAT).

CAT deals with two co-existing thought systems such as Science and IKS that tend to move back and forth in an attempt to generate an optimum cognitive state. A dominant conception such as science needs to recognize and facilitate the significance of an emerging conception (IKS). Argumentation-based instruction assumes teacher intervention, learner participation and an interaction through reflection and exchange of ideas.

Every culture has its own Indigenous Knowledge System (IKS); every learner can therefore make a fruitful contribution to an argumentation-based instruction. Driver et al. (1994:7) suggests that: ‘If knowledge construction is seen solely as an individual process, then this is similar to what has traditionally been identified as discovery learning’. Teachers need to create learning and teaching environments where learners are free to participate.

The analysis, findings and recommendations attempts to determine the effectiveness or otherwise of a dialogical argumentation- based instructional model in capacitating learners’ understanding of pollution. In pursuance of this aim answers will be sought to the following questions:

- What conceptions of pollution do grade 10 learners hold?
- What process skills do grade 10 learners use to perform cognitive tasks on water pollution?
- Are the learners’ conceptions of water pollution related to gender, age or socio-cultural backgrounds?
- Is there any difference in the performance of learners exposed to an argumentation-based instruction and those who have not been so exposed?

Method
Research was conducted at a resident school. The research design is as follows:

The quantitative method entailed a quasi-experimental design to measure the differences between the experimental and control groups. The following format was used for the quantitative design:

\[ O_1 \times O_2 \quad (E) \]

\[ O_3 \quad O_4 \quad (C) \]

\( O_1 \) (pre-test) and \( O_2 \) (post-test) \( \in \) that was subjected to an intervention, \( x \), which is the Dialogical Argumentation Instruction. \( O_3 \) (pre-test) and \( O_4 \) (post-test) was the control group (C) and was not subjected to Dialogical Argumentation

This paper specifically deals with the challenges of conducting research especially in the area of instrumentation, piloting, time-frames and socio-cultural phenomena.

Results and Discussions
Learners’ Conceptions of water pollution.
Pre-test Results
The mean is a useful statistic for measuring the concept of average in a distribution. It measures the values of each score in a distribution and forms an important component in interpreting central tendency. However, it is very sensitive and can be easily affected by extreme scores in a distribution. Hence, for ease of reference and to avoid interpretation errors, it is better to convert mean scores into mean percentages (Ogunniyi, 1992).

Table 1.1 below shows the learners’ performance on the WPAT with regard to gender at the pre-test stage.

**Table 1.1: Pre-test Scores obtained by learners on the WPAT.**
Judging by the mean percentages of 21.27% and 21.75% for E and C respectively, it is obvious that they are low. However, the relatively low standard deviations of 2.18 and 4.05 for E and C respectively, are indicative that the two groups were comparable. The t-test for the pre-test scores for both groups stood at 0.29. This value is less than the critical value required to reject the null hypothesis, namely, 1.684. Since the obtained value is less than the critical value, we cannot reject the null hypothesis suggesting no significant difference between the pre-tests of the E and C groups. This further reinforces the idea of comparability of the groups at the pre-test stage. Both groups performed similarly in the WPAT at the pre-test stage. A difference at post-test stage, if any, could then be attributed to the treatment.

Based on the t-test scores for the pre-test, there was no significant difference between the boys and the girls. The mean percentages for C of both genders were very close, i.e. 22.04% and 21.53% for the girls and boys respectively, thus indicating the comparability of the two gender groups. The t-test score of 0.164 is less than the critical value of 1.729 needed to reject the null hypothesis at p = 0.05. Thus, the differences between the boys and girls in the control group, is not statistically significant at the pre-test stage. Also, the mean percentages for E were 22.42% and 20.0% for the females and males respectively. This suggests that the females had a slightly better understanding of the topic than the males. The t-test score of 1.57 is less than the critical value of 1.729 needed to reject the null hypothesis at p = 0.05. Thus, the differences between the females and males in both groups are not statistically significant at the pre-test stage.

Relative effectiveness of the treatment.

The fourth research question is concerned with finding out the effect of the treatment, i.e. argumentation-based instruction on the learners understanding of water pollution. The purpose of the pre-test was to determine the nature of the learners’ conceptions of water pollution. The E group was exposed to a three week treatment involving the use of Toulmin’s argumentation Pattern (TAP).

The effect of Argumentation-Based instruction (ABI)

The historically depriving teaching method i.e. lecture method minimizes learner participation. Researchers have used TAP an argumentation model to determine the teachers’ and learners’ understanding of the nature of science (Driver et al,2000; Erduran et al,2004; Ogunniyi, 2004, 2006, 2007 a&b; Osborne et al, 2004; Simon et al, 2006). They have found argumentation and dialogue to be useful tools for enhancing teachers’ and learners’ conceptual understanding.

The use of ABI seemed to have achieved the desired effect as it is reflected in the post-test results.
Post Test
At the end of the implementation period, the two groups were subjected to the WPAT as a post-test. In a study where the post-test differs from the pre-test, it is dubitable whether the measuring instrument reflects the same underlying conceptualization and thought processes in the post-test as in the pre-test, thus the use of the same WPAT for both pre- and post-test. As stated earlier, groups E and C wrote a pre-test. Group E was exposed to the treatment, i.e. argumentation based instruction, group C was exposed to the traditional lecture method. The null hypothesis posited for testing was that there would be no difference in the performance of the learners exposed to argumentation based instruction and those not so exposed. The learners’ performances are displayed in Table 1.2

Post-test statistical summary.

Table 1.2: Learners’ performance on the WPAT at the post-test stage:

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Mean %</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>21</td>
<td>24.86</td>
<td>41.43</td>
<td>2.3</td>
</tr>
<tr>
<td>C</td>
<td>21</td>
<td>17.1</td>
<td>28.49</td>
<td>3.65</td>
</tr>
</tbody>
</table>

The above table represents the average performance of groups E and C. Looking at the overall picture, although no group achieved a mean % of above 50%, the group that performed the best was E with a mean % of 41% and C 28%. The t-statistic for E and C is 8.3 which is higher than the critical value of 1.684 at p = 0.05. In other words, the null hypothesis suggesting no performance difference between the two groups is rejected. There is a difference in performance between the learners taught by argumentation based instruction and those taught by lecture method.

Data collected at the post-test stage.
Judging by the means of the pre-test of about 21.3% for E and 21.8 % for C and the post-test mean scores of about 41% (E) and 28% ( C ), one can see a difference between the means of the two tests for both groups at the post-test stage.

Table 1.3: Pair-wise Comparison of the scores at the pre- and post-test stages

<table>
<thead>
<tr>
<th>Group E</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Group C</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>12.76</td>
<td>24.86</td>
<td>13.05</td>
<td>17.1</td>
<td></td>
</tr>
<tr>
<td>Mean %</td>
<td>21.27</td>
<td>41.43</td>
<td>21.75</td>
<td>28.49</td>
<td></td>
</tr>
<tr>
<td>SD</td>
<td>2.18</td>
<td>2.3</td>
<td>4.05</td>
<td>3.65</td>
<td></td>
</tr>
<tr>
<td>t-test</td>
<td>$t_{\text{obs}}$ (2.19) &gt; $t_{\text{crit}}$ (1.725)</td>
<td>$t_{\text{obs}}$ (0.884) &lt; $t_{\text{crit}}$ (1.725)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Obtaining a t-value of 2.19 and 0.884 for the E and C groups for the pre- and post-test scores against a critical value of 1.725 is indicative of significant difference for E, but not for C between the pre-and post-test mean scores. This implies that the null hypothesis has to be rejected for E, as there is a significant difference between the two tests. However, null hypothesis for C cannot be rejected. Since both groups were exposed to the same teaching and learning materials, (except for the argumentation based instruction (ABI) for E), the higher t-value was probably as a result of the argumentation model learners in that group were exposed to. As one of the E learners said, “My opinion is valued in argumentation.”
SUMMARY, CONCLUSION AND IMPLICATIONS

INTRODUCTION
The main goal of this study was to explore grade 10 learners’ conceptual understanding of water pollution, using argumentation-based instruction (ABI) as a teaching tool. In addition the effects of gender and age difference on the learners’ conceptual understanding of water pollution were examined. This chapter summarises the major finding and examines the implications of such findings for curriculum development and instructional practice. Finally, the chapter offers some suggestions for various stakeholders.

SUMMARY OF FINDINGS
As outlined in chapter three, two groups of grade 10 learners consisting of the experimental group (E) and the control group (C) participated in the study. Groups E and C wrote a pre-test, E was exposed to ABI while C the control group was not so exposed. The major findings of the study are presented below:

• Based on the pre-test data, there was no significant difference between the performances of groups E and C, i.e. they were quite comparable.
• At the post-test level, however though there was an improvement in the performance in both E and C the former clearly outperformed the latter in most of the items. This was probably due to the fact that E was exposed to ABI while C was exposed to the traditional lecture method. The significant difference between E and C were therefore attributed to ABI to which the former was exposed.
• Although generally, ABI seems to have had a positive effect on the understanding and learning of the learners, judging by the few negative comments made by teachers in other research instances (Newton et. al., 1999), e.g. teachers negative views:
  (i) Time constraints and the Curriculum;
  (ii) The difficulties of managing discussion;
  (iii) Teacher skills and views of Science.
• From the analysis of the focus group interview as well as excerpts from WPAT it seems clear that the method (i.e. ABI for E) had a significantly positive impact on the learners’ understanding of water pollution.
• In both the pre-test and post-test, there was no significant difference between the performances of the girls and the boys involved in this study.

INSTRUCTIONAL AND CURRICULUM IMPLICATIONS OF THE FINDING
Looking at the data provided , one could see that learners seemed to have made a significant attempt to make sense of the concepts involved in this study. They even did their best in debating and trying to understand water pollution as well as attempting to use ABI as a learning tool. Although lively discourse and participation led to a noisier classroom, it was certainly much better than having a dull lesson.

The foregoing results suggest that there is a need for teachers to consider using a combination of instructional strategies (including ABI) in their teaching. Also, the results of this study suggest
that traditional expository method is not as effective as the alternative method in which ABI plays a significant role in helping learners understand water pollution. At the beginning of this study the learners had a poor understanding of water pollution and associated concepts. They lacked the necessary motivation for their studies. However, in view of the outcomes of this study, it is apposite to suggest that the instructional approach adopted in the study could serve as a useful means to motivate them in developing a positive attitude towards their studies. As their achievement improves as a result of their conceptual understanding, they might become more confident to find their study a meaningful learning experience (e.g. see Horton et al., 1993).

As has been confirmed in a plethora of studies, (the use of ABI) enhanced the learners’ understanding of water pollution. The potential of this instructional tool for enhancing learners’ understanding of other science concepts is worthy of further consideration.

As a practice based on constructivist epistemology, the use of ABI by teachers could help them interrogate learners’ prior knowledge and to seek for ways to make necessary adjustment in their own understanding of a given phenomenon. The process whereby learners seek for a meaningful integration or incorporating the new conceptual understanding into their overall cognitive structure is what Ogunniyi (1995, 2002, 2004) calls contiguity learning or what Aikenhead & Jegede (1999) call smooth border crossing and/or secured collateral learning process.

In teaching any concept the teacher should not only consider the learners’ prior knowledge of the concept in question but should also integrate what is taught in class (science) to their everyday lives (IKS). This will enable the learners to know that science is not only what is taught in class but a part of their everyday experiences. If learners are made aware of this, their attitude towards science as a subject might improve and consequently, their performance might also improve. The inclusion of relevant controversial issues, like water pollution, use of pesticides and the like that are affecting the learners’ lives could also be used to arouse their interest in the lesson. Although this approach in some cases may be problematic, particularly for learners from traditional societies who are not used to open formal confrontation or argumentation. There is also the danger of shifting the learners’ focus from the real scientific concepts to social issues. However, this approach should be introduced into the lesson in such a way that they form part of the class discussion.

The integration of the everyday science in teaching should not only end in class but should be accommodated in the test and examinations. The emphasis of the newly revised Curriculum 2005, particularly Learning Outcome 3 (LO3) expects learners to develop and be able “to demonstrate an understanding of the interrelationships between science and technology, society and the environment” (Department of Education, 2002, p.10). However, in the spirit of constructivism and current debates about water scarcity, water borne diseases, genetic engineering, etc., the inclusion of socio-scientific issues or the application of science to social issues seems long overdue.

RECOMMENDATIONS
A further research needs to be carried out on whether ABI does really have an effect on learners’ attitudes to science as well as looking onto the integration of science and IKS. The use of TAP enabled me to identify arguments and assess their quality. This needs to be done on a bigger scale involving several schools from different backgrounds. Also the duration of the study should be much longer than was the case in this study.

A further study also needs to be done on the effect of integrating everyday science with school
science. I believe this could be an answer to a lot of problems facing the teaching of science. One of these problems is the phobia that science is a difficult subject meant only for individuals with a high intellect. It is hoped that as more data about learners’ conceptual development become available, new and effective strategies would be designed to cater for their needs. It is also hoped that the approach used in this study, especially the inclusion of a controversial topic – water pollution, and the findings would stimulate further studies in the area in attempting to eradicate the problem relating to water and water shortages.

CONCLUSION
In this study, the learners’ conceptions of water pollution were examined. After the study learners showed more positive attitudes towards science. While the majority of the learners seemed to have made some progress in their conceptual development as a result of their exposure to ABI, a few learners struggled with the approach. It is hoped that the implementation of ABI to a larger group of learners and for a much longer period would ameliorate the above problem.

REFERENCES
South African Science Teachers’ Conceptions of Teaching Science and of the New Curriculum

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This paper is based on a study completed as part of the Honours programme in Science Education I completed at Wits University in 2009. The aim of this phenomenographic study was to identify what conceptions experienced South African science teachers hold of science teaching and of the National Curriculum Statement for Physical Sciences (NCS). A purposive sample of four experienced teachers was chosen and semi-structured interviews were conducted. I conducted two interviews and a fellow researcher conducted the other two. We shared our data and I then coded and analysed the transcripts and shared my analysis with my fellow researchers in a research group. The analysis revealed an inclusive hierarchy of conceptions of science teaching based on the methods teachers use in teaching. The analysis also identified conceptions teachers have of the new curriculum. This research shows that these conceptions of teaching are similar to those reported in the literature and identifies where teachers’ conceptions of teaching are aligned to the learner-centred approach of the curriculum. However, the teachers’ conceptions of the curriculum are mainly focussed on science content and do not emphasise practical inquiry or Nature of Science and its relationship to society and the environment.

Introduction

The process of curriculum reform in South African schools reached a critical milestone in 2008. The Grade 12 learners of 2008 were the first learners to complete 12 years of education under the Outcomes Based curriculum. At this critical point, reflection on the process of curriculum reform seemed appropriate. Although there had been some analysis of the new curriculum, based on learner performance (Department of Education, 2008), these sorts of studies do not give a real reflection of systemic transformation since learners are not a permanent part of the system. A more realistic and valid evaluation of the effect and extent of curriculum change needs to include a focus on teachers and their experiences of teaching science.

The idea that teachers have different conceptions of teaching is not new and has been extensively explored, particularly in Higher Education (Kember, 1997). A conception of teaching science is a personal framework that includes, amongst others, the teacher’s knowledge and beliefs about the subject, the teacher’s previous experience of teaching and learning and the teacher’s knowledge of the learners being taught (Thomas & Pedersen, 2003). The importance of these conceptions is that they do influence the way a teacher functions in the classroom. So investigating teachers’ conceptions of science teaching may be a useful indicator of curriculum reform. By comparison, the National Curriculum Statement (NCS) provides an explicit view of the ‘kind of teacher that is envisaged’ (Department of Education, 2003). The detailed descriptions of the many roles listed, form conceptions of teaching within the framework of the new curriculum. I therefore feel that it would be very useful to compare these to the conceptions teachers have of science teaching. However, the problem is that there does not seem to be any published research into the conceptions more experienced South African science teachers hold of science teaching. There is also uncertainty about whether teachers hold conceptions similar to the conceptions as those envisaged by the NCS.

The research questions I therefore attempted to answer are:

1. What conceptions of science teaching do experienced Physical Science teachers in South Africa hold?
2. What conceptions of the NCS curriculum do experienced Physical Science teachers in South

163
Africa hold?

Theoretical Frameworks

This study required qualitative research. Creswell (2007) identifies four different paradigms or worldviews that should shape qualitative research, namely post-positivism, social constructivism, advocacy/participatory and pragmatism. I choose social constructivism as the framework for my research since within this paradigm the researcher is concerned about how people come to gain meaningful understanding of their environment. Creswell (2007) suggests that the goal of research within this paradigm is to focus on the ‘participants’ views’ of an experience or a phenomenon. It is these ‘participants’ views’ that form teachers conceptions which are the focus of this study. The second reason for choosing social constructivism as a framework is that this research was conducted within the framework of a research group. Although each researcher collected data, analysed the data and recorded the findings individually, the data collected was shared and individual interpretations of the data tested within the group. In this way there was a social construction of our understanding of research and of the specific questions I wanted to answer. Thirdly, Creswell (2007) indicates that the framework of social constructivism is suited to phenomenological studies and studies based on Grounded theory. Phenomenography is a research methodology developed in the 1970s to investigate students’ approaches to learning in higher education by Ference Marton and Roger Säljö, working independently (Richardson, 1999). In phenomenographic studies, the researcher aims to identify the differences in the way participants experience a phenomenon. In this study I used a Grounded theory approach since I hoped to find a theory or model emerging from the data captured and analysed in my phenomenographic study.

Literature Review

There has been significant research into the conceptions of teaching in three contexts namely, in higher education, in the education of pre-service science teachers and in secondary school science teachers. Kember (1997) identified fourteen studies that focused on conceptions of teaching held by University academics. These studies were mainly conducted in the early 1990s and were developed independently of each other. Since the focus of my research is not on conceptions of teaching broadly but specifically on the conceptions science teachers hold, I focused my review on studies that included science teachers. Of the research reviewed by Kember, three studies included science teachers, namely, the research done by Samuelowicz and Bain (1992) which included five science educators and eight social science educators and the research by Prosser, Trigwell and Taylor (1994) which included twenty four science educators. Although the approaches and labels of the conceptions these researchers are different, the commonalities between them are emphasised by Kember’s analysis (1997) and give support to the assumption made by Samuelowicz and Bain (1992) that there are a limited number of conceptions of teaching. In addition, both Samuelowicz and Bain (1992) and Prosser et al (1994) show how their conceptions can be simplified into two groups, one that is essentially teacher centred and the other learner centred. Kember (1997) describes these groupings of conceptions as a ‘teacher centred / content-orientated pole’ and a ‘student-centred / learning-orientated pole’.

In the context of pre-service teachers, Thomas and Pedersen (2003) used the Draw-a-Science-Teacher Test Checklist to explore the conceptions that pre-service elementary science teachers held. They found that many of the participants had a very teacher centred view of teaching. This finding is supported by work done by Eick and Reed (2002) who investigated what influenced pre-service teachers when implementing an inquiry based approach in their field work. They found that pre-teachers were strongly influenced by their own experiences. Student teachers who had developed an image of teaching as being teacher centred, based on their past experiences, were not able to adopt a more learner centred inquiry approach during field experiences.

There seems to be very little published research on the conceptions science teachers at secondary schools have of science teaching. I found only two published articles one by Boulton-Lewis, Smith, McCrindle, Burnett and Campbell, (2001) and one by Gao and Watkins (2002). Boulton-Lewis et al included Australian science teachers in their sample of secondary school teachers but Gao and Watkins worked only with physics teachers from Guangzhou province in the People’s Republic of China. Boulton-Lewis et al (2001) also acknowledges the limited research on secondary school teachers’ conceptions of teaching and learning. Both Boulton-Lewis et al (2001) and Gao and Watkins (2002) based their research on the work done in higher education and found that
the conceptions of secondary school teachers correspond fairly closely to the conceptions of teachers at tertiary institutions. In the conceptions they identified there is a continuum of conceptions from a teacher centred orientation to a learner centred orientation.

Methodology

My research formed part of work done by a research group consisting of four BSc Honours students and our supervisor, Dale Taylor. The research group met weekly throughout the research process. We prepared a common interview schedule consisting of open ended questions which we tested in the group. Conceptions teachers hold are not tangible, fixed or something they may record themselves. It also seems likely that direct questions in the interview process may influence teachers unduly. Martin and Lueckenhausen (2005) identified metaphors that described individual teacher’s conceptions of teaching after analysing data collected from a large phenomenographic study. We decided to use pictures of teaching roles as metaphors as the first question in our instrument. The intention of using was to get the teachers to be more relaxed and to describe their conceptions of teaching without using teaching jargon associated with Outcomes Based Education. We added two questions that interrogate the meaning behind the metaphors used and focus on the teaching strategies used. Additional questions about the teaching environment, practical work and the curriculum were added. Each researcher conducted two interviews which were audio recorded and then transcribed. The data from all these interviews was shared with the research group. For my research, a purposive sample of four teachers who all have more than four years teaching experience was chosen. These teachers have all been teaching Physical Sciences to learners in Grade 10 to Grade 12 during the implementation of the NCS. We worked collaboratively and individually on the transcripts and identified key words related to the teachers’ description of their experience of science teaching. We then grouped these key words into themes but we were unable to find significant differences in the individual teachers’ descriptions. At one of our research group meetings, we discussed our progress with Prof. Michael Prosser and Prof. Keith Trigwell, the authors of numerous publications on conceptions of teaching and learning. In this meeting they explain that in a phenomenographic study, conceptions of teaching and learning form an inclusive hierarchy that emerges by looking at the data as a whole. When I re-examined the data as a whole, I found an inclusive hierarchy of three conceptions of science teaching. Further analysis of the data also revealed conceptions teachers have of the new curriculum.

Discussion

The model I developed from the analysis of the data is based on the methods teachers use in their teaching of Physical Sciences and is illustrated in Figure 1 below.

Figure 1. Conceptions of teaching science

The conceptions can be distinguished from each other by considering the role of the teacher, the role of the learner and the focus of the teaching, as summarised in Table 1.
Table 1. Summary of the dimensions of conceptions of science teaching

<table>
<thead>
<tr>
<th>Conception A</th>
<th>Teacher</th>
<th>Learner</th>
<th>Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching science as presenting science content</td>
<td>Active &amp; Dominant</td>
<td>Passive</td>
<td>Knowledge</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conception B</th>
<th>Teacher</th>
<th>Learner</th>
<th>Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching science as modelling science thinking</td>
<td>Leading by Engaging</td>
<td>Actively engaged</td>
<td>Knowledge &amp; Thinking skills</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conception C</th>
<th>Teacher</th>
<th>Learner</th>
<th>Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching science as empowering learners to do science activities</td>
<td>Supportive</td>
<td>Active &amp; Leading</td>
<td>Skills of accessing knowledge</td>
</tr>
</tbody>
</table>

Further analysis of the data revealed conceptions teachers have of the new curriculum. There did not appear to be significant differences in the conceptions of the curriculum so it was not possible to organise these conceptions into an inclusive hierarchy. To summarise teachers conceptions of the NCS I organised the data around the three Learning Outcomes and then developed a model to describe these conceptions, shown in Figure 2.

![Figure 2. Teachers’ conceptions of the NCS curriculum](image)

I drew the three ovals of different size to indicate the emphasis the teachers place on each of the Learning Outcomes in their science teaching. Clearly, the focus of the teachers is on aspects of Learning Outcome 2, the largest oval, Learning Outcome 1 is smaller indicating less focus and Learning Outcome 3 is the smallest oval indicating that teachers expressed very limited ideas about this Learning Outcome.

The lines and arrows between the ovals show the relationship between the Learning Outcomes. Notice that there are lines and arrows between Learning Outcome 2 and Learning Outcome 1 and between Learning Outcome 2 and Learning Outcome 3. I drew the size of each of the lines and arrows differently to illustrate the relationships that emerge from the conceptions teachers hold of these aspects of the curriculum.

The model illustrates that there is a relationship between Learning Outcome 2 and Learning Outcome 1. I propose that these teachers have a conception of the curriculum which is focused on the construction of science knowledge but they believe that the construction of knowledge can be enhanced by doing demonstrations of
experiments and by giving attention to problem solving too. The line between Learning Outcome 2 and Learning Outcome 1 is wide and has arrows at both ends. The reason I have made this line wide is to emphasise the strong relationship between Learning Outcome 2 and Learning Outcome 1. I also added arrows at both ends of the line to indicate that science knowledge will inform both practical inquiry and problem solving and that these activities will enable the learners to construct and apply their science knowledge. So in essence there is a two way process. However, the size of the arrow head is larger pointing from Learning Outcome 2 to Learning Outcome 1 because it seems to me that teachers use both practical demonstrations and problem solving to reinforce the concepts and knowledge they have already established with their learners. There were only a few references to strategies that either begin with practical inquiry or problem solving. Hence, the arrow pointing from Learning Outcome 1 to Learning Outcome 2 is smaller in size.

There is also a line drawn between Learning Outcome 2 and Learning Outcome 3 indicating that teachers believe that there is a relationship between these Learning Outcomes. I have drawn the line thinner to emphasise this is relationship is not seen as strong as the link between Learning Outcome 2 and Learning Outcome 1. There are also small arrow heads on both ends of the line. I suggest that this represents how teachers may use an issue in society that is relevant to the learners to introduce science content. Alternatively, teachers may help learners construct knowledge about a topic and then show them where this is applied in the real world. The data did not show that either of these links was favoured and so I have kept them both the same size.

It is important to note that there is no arrow between Learning Outcome 1 and Learning Outcome 3 as there were no references to any relationship between these aspects of the curriculum in the data collected. However, I believe that there could be a link between these areas if teachers’ choose to investigate issues in society.

Conclusion

This research has identified conceptions that some South African Physical Science teachers hold of science teaching and of the NCS. In addition, we showed where teachers’ conceptions of teaching are aligned to the learner-centred approach of the curriculum and identified where teachers’ conceptions of the NCS are not aligned to the intended policy. I propose that research into the conceptions teachers hold may therefore be a useful indicator of curriculum reform and may be helpful in assisting the ongoing process of curriculum reform.

References


Teacher Roles in Implementation of the Natural Sciences Curriculum of the National Curriculum Statement

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Abstract
The introduction of the National Curriculum Statement and its predecessor Curriculum 2005 revolutionised teaching and learning in South Africa. Whether teachers liked it or not they had to implement it as a replacement for an otherwise abhorrent one. Teachers were to teach the curriculum in a learner-centred way using a variety of strategies. They were caught unaware. The aim of the study was to investigate how well teachers implemented it. Literature was reviewed to look at the theoretical underpinnings of the curriculum and how natural science teaching may be achieved at the senior phase and factors which may affect implementation. Questionnaires, interviews and classroom observation were used to find out about teacher implementation and to investigate factors that may affect implementation. Based on the findings it was recommended that the Department of Education should formulate a policy of continuous education on the implementation of curriculum. At the time of compiling this report, the Department of Education had announced further changes to the curriculum.

Key words: implementation, National Curriculum Statement, Natural Sciences, Learner centred education, teaching strategies.

Introduction and Background
The introduction of the National Curriculum Statement (NCS) in South Africa meant a change in curriculum content, teaching strategies, assessment practice, and educator and learner roles in the classroom. It was introduced because, among other factors, evidence from the Trends in International Mathematics and Science Studies (TIMSS) for 1995, 1999 and 2003 indicated a poor trend in learner performance in science in South Africa. Internationally South Africa was one of the countries that performed poorly in Grade 8 Science. Reddy (2006) says that when the results were analysed nationally, it was found that the North West Province was beaten by all the provinces except the Eastern Cape and Limpopo. The NCS was aimed at producing critical and reflexive individuals. Curriculum 2005 (an earlier version of the curriculum) and the National Curriculum Statement required educators to account for the success or failure of their learners (Department of Education (DOE), 2008: 3). Educators were to provide learners with the opportunities to develop abilities that could be used in various situations. Learners were therefore to be involved in activities that needed critical thinking processes. The focus was on what learners should know and be able to do (knowledge, skills, attitudes and values) (DoE, 2002a).

The natural sciences introduced methodologies based on learner involvement. It required an interactive teaching-learning approach between educators and learners. Learners were to explore, discover,
discuss and meaningfully construct scientific concepts and relationships in contexts that involve real
life situations. As a consequence many teachers were caught unprepared to implementation the
curriculum effectively.

The teaching of natural sciences required teachers to be competent in content knowledge and
pedagogical content knowledge as well as curricular knowledge (Brickhouse and Tobin, 1992). The
challenges which faced teachers therefore seemed enormous and (one wonders if) the teachers already
in the field were not ready and efficient to handle the expectations of the new curriculum. Most of the
educators, especially the old ones, were used to teacher-centredness. The manner in which the
Department of Education (DoE) conducted its advocacy campaigns or the educator training offered in
in-service courses were insufficient to win over the teachers as collaborators in the implementation of
the curriculum (Pudi, 2006, on line). To make matters worse, the curriculum presented numerous
terminologies difficult for teachers to comprehend.

Statement of the problem
The problem that was investigated in this study was therefore to find out about the roles which Senior
Phase Science teachers in the Mafikeng area played in the implementation of the Natural Sciences
Curriculum of the National Curriculum Statement.

Research questions
The study was guided by the following research questions:
• Which role is played by Senior Phase Science educators in the implementation of the NCS in
natural science teaching?
• What challenges Senior Phase Science educators encountered in the implementation of the
curriculum? and,
• What suggestions may be made to the teachers to ensure successful continuous implementation of
the curriculum?

Literature and Theoretical framework
The theoretical basis of the NCS is Outcomes Based Education. According to Malcolm (1999), the
principal feature of outcomes-based education is a distinction between inputs and outputs. Outputs
(also described as standards) are centrally designed and prescribed, while inputs are discretionary, and
generated and managed locally. Inputs include what teachers and learners bring to learning, indigenous
particularities and priorities, textbooks, management and support systems. Since these vary across
learning contexts, the key input of what is taught and how it is taught should not be rigidly prescribed.

Spady (1994:1) says that Outcomes Based Education means a clear focusing and organising of
everything in an educational system around that which is essential for all students to be able to do
successfully at the end of their learning experiences. This means starting with a clear picture of what is
important for students (learners) to be able to do, then organizing the curriculum instruction, and
assessment to make sure this learning happens. According to the DoE (2000), the South African
version of OBE adapts Spady’s ideas. It similarly sees OBE as “in essence...defining, organising,
focusing and directing all aspects of a teaching system in relation to what we want all learners to
demonstrate successfully when they exit the system....”(p.19). OBE is learner-centred. It takes the child
as the starting point in education, stressing the need for awareness of the whole child. Learner-centred
education believes in the child’s potential. It focuses less on what each learner may become and more
on what each learner already is. Learners need an environment that allows them to proceed at their own
pace in developing skills without being compared with someone else. According to Gestwicki (1999),
learners should be taught in an atmosphere of co-operation rather than a spirit of competition. It is in
these ideas that OBE seems to share the same principles with Constructivism. This is because
Constructivism also shares the assertion that human knowledge and experience entails the active participation of the individual (Bishop and Carpenter, 1993). To be able to teach to bring out the best in learners, the teachers should have had knowledge of a variety of teaching and assessment strategies in order to have provided multiple opportunities for learners to learn and demonstrate achievement. This could have helped the teachers to see what the learners were capable of doing and also helped the educators to evaluate their teaching method(s).

Bishop and Carpenter (1993) continue to say that Constructivism takes as its starting point the idea that pupils are active learners who come to science lessons with certain preconceptions of how the world is structured and ordered. It is this aspect of the learners’ knowledge that has to be reinforced and developed to achieve success. Constructivism therefore supports OBE in a sense that it also fosters critical thinking and creates active and motivated learners. The constructivist teacher therefore becomes one of many resources that the student may learn from, not the primary source of information. The teacher encourages thoughtful discussion among learners in using cognitive terminology such as “classify”, “analyse” and “create” when framing tasks. The teacher encourages and accepts student / learner autonomy and initiative and is willing to let go of classroom control. (Hanley,1994:3). Yager (1991) also encourages teachers to involve learners in seeking information that can be applied in solving real – life problems. He suggests that learning should be extended beyond class periods, classroom and the school. The senior phase teacher should be aware of these and apply them in his/her teaching.

The Implementation of the NCS

In South African schools teaching had been teacher – centred with the learner treated as a tabula rasa on which knowledge was poured as if into an empty bucket. In the new dispensation, educators are obliged to introduce a child-centred approach to teaching and learning. Old models and traditional structures are not fully in line with the OBE approach. It is therefore important for teachers to consciously make a paradigm shift to introduce a child-centred approach in teaching (DoE, 2000).

According to Muwanga-Zake (2000, online) teachers claim that lack of Science equipment and laboratories prevent them from teaching science practically. However, there is evidence that teachers who have equipment do not use it. It appears therefore that apart from workloads, the main reason why teachers do not use practical work is that they are deficient in practical skills and do not understand the science concepts they are supposed to teach. This claim is well demonstrated in schools that have science equipment and who do not use or who dont know how to use these. In the majority of schools, Muwanga Zake (2000) reports that science kits in schools he visited were found to have gathered dust. Hattingh (2007, online) says that a good teacher will always find ways to improvise if she/he really needs to do practical work. A lazy teacher, on the other hand, fails to do practical work even if she/he has resources. The success of any curriculum depends on how it is accepted and understood (ANC, 1995:8).

According to Pudi (2006, online), the understanding of the curriculum by educators encompasses the philosophical underpinnings of the curriculum and the empirical understandings--(i.e., classroom realities such as developing learning programmes, assessment and general teaching or facilitation). When teachers have acquired the knowledge and understanding of the curriculum and its unfolding nature, they will be in a position to interpret the stipulations of the policy document with insight and to be able to develop learning programmes that address the needs of the curriculum. It is this fact teachers must know to play their roles effectively.
How Teachers may teach science in the classroom

Driver, Asoko, Leach, Mortimer and Scott (1994:5) give the view that there is interplay among various factors of personal experience, language, and socialization in the process of learning science in the classroom. To promote learning the teacher can give helpful interventions such as “what do you mean? How did you do that? Why do you say that? How does it fit in with what she said? Could you give me an example? How did you figure that? In this the teacher’s activities are thus portrayed as promoting thought and reflection on the part of the learner with requests for argument and evidence in support of assertions.

Tobin, Treagust and Fraser (1998) assert that the exemplary science teacher manages instruction and learners as to maximize student engagement; that the
- academic work has a high level of cognitive demand
- the exemplary teacher maintains a favourable psychological learning environment in his classes.
- The exemplary teacher uses the laboratory in an enquiry mode and as an integral part of the course.

Kwayisi (2006) summarises these by saying that the successful implementation of the ideals of the NCS needs teachers who would have a good knowledge base of the subject as well as the use of different skills to pass on knowledge to learners. The teacher must be able to communicate effectively with learners.

We state that the central point in these arguments is how effectively teachers can teach natural sciences for the benefit of learners. The main aim of the curriculum is to produce a competent, independent and creative learner who is also a critical thinker. We need teachers who would understand the current classroom dynamics and be adept in adapting to suit changing scenes. Curriculum innovation and change should be continuous towards improvement. The government has announced a modification of the national curriculum statement towards improvement (Department of Education, 2010) and teachers would need to be in-serviced to implement this effectively.

Research Design and Methods.

Population and Sample of the study

The target population was the Senior Phase Natural Sciences teachers of the schools in the nearby villages, locations and town of Mafikeng. The research was focused on teachers from twenty schools, 10 urban and 10 rural. All the schools were previously disadvantaged. The number of Natural Sciences teachers selected per school was two making a total of 40. The reason for selecting teachers from both urban and rural schools was to find out if teacher roles were similar and if they faced the same challenges. The 40 teachers purposefully selected, also formed the sample.

Data collection.

In trying to answer questions related to the research, both qualitative and quantitative methods were used. Questionnaires, interviews and observations were used for data collection. The use of these instruments was to enhance validity.

Questionnaires

Quantitatively, a survey was conducted to collect data through the use of questionnaires. The questionnaire contained open and closed questions on school demography, teaching and learning support, preparation for teaching, lesson presentation, teaching strategy, assessment practice, teacher
support and development and on problems teachers faced and suggestions on how to improve the situation. Schools were visited and permission sought to conduct the research. The respondents were made aware that participation was voluntary. Their anonymity was respected and confidentiality was assured (Resnik, 2007). Data were collected within two months, from July to August 2009. All 40 teachers answered the questionnaires.

**Interviews**

Interviews were conducted in a face-to-face situation with one interviewee at a time. Cunningham (1993) states that a one- to -one interview allows the interviewer to explore issues in depth with the interviewee. It was to provide the opportunity to give a full detailed explanation of the purpose of the study to the respondents and ensure that they understood what was expected. The interviews were recorded with a cell-phone recorder. Four educators, two urban and two rural, were interviewed and recorded. Each interview took approximately ten to fifteen minutes. Questions used in the interviews were structured to follow questions in the questionnaire. Each interviewee was asked questions in the same order.

**Observations**

Classes of the four teachers interviewed were visited and two lessons observed each. Before each lesson, the educator to be observed gave the researcher a copy of the lesson plan. The observations were based on basic classroom dynamics, teacher and learners activities, whether there were set outcomes in the lesson plan, the types of questions used and assessment practices. Observations on these items were recorded in note books. Special occurrences were also recorded.

**Data analysis and interpretation**

Quantitative data analyses were presented in frequencies and percentage tables. Interviews and observations were analysed under themes similar to questionnaire themes.

**Analysis of questionnaires**

Responses from educators were analysed as indicated below.

**Number of Senior Phase learners**

6 (15% three form rural and three from urban) teachers indicated that there were less than 100 Senior Phase learners in their schools, 12 (30% of “n”) indicated their schools had between 100 and 150 learners. Sixteen (40%) teachers said that there were about 500 Senior Phase learners in their rural schools, while the 6 remaining teachers (15%) indicated that there were over 500 Senior Phase learners in their schools. The majority of schools therefore had about 500 learners in the senior phase.

**Teaching and learning support**

In response to questions on this, 95% (both rural and urban) respondents indicated that they only used the National Curriculum Statement policy (Grades R-9) for Natural Science provided by the Government for teaching. 92% also used the Teachers Guide for the development of Learning Programmes. 95% respondents made use of the Assessment Guidelines for teachers. 75% of the rural teachers said they had no laboratories while 40% said they had science kits. Sixty-five percent (13/20) of the urban respondents indicated that their schools had science laboratories and 16 (80%) indicated that their laboratories were well-equipped and the laboratories were used for teaching. The urban respondents indicated that they had chemicals and apparatus for Senior Phase work. Thirty (75%) teachers indicated that their learners had science textbooks. These factors were corroborated to by the school visits and interviews.
Lesson presentation
9 (45%) rural and 18 (90%) urban teachers indicated that they explained lesson outcomes at the start of lessons to learners. However, 75% (both rural and urban) of the respondents indicated that all lessons were built on learners’ prior knowledge. 8 (40%) rural and 17 (85%) urban teachers said they used physical and concrete objects in their teaching. All the respondents (100%) also allowed learners to work individually, in pairs or in groups. 30 (75%) of the respondents said they gave learner activity sheets with instructions and all of them said they offered help whenever learners needed one and 36 out of 40 of the teachers gave learners the chance to report back on their activities.

Responses from interviews and observations made reinforce the above assertions in that all four interviewees indicated that teaching Senior Phase Natural Sciences was challenging. They explained that resources were either absent or insufficient. All four interviewees indicated that they used departmental guidelines for planning, teaching and assessing. The teachers said that learning outcomes (LOs) and assessment standards (ASs) were taken into consideration when they planned lessons. One interviewee indicated that some schools have lesson plan templates for writing lesson plans. One other interviewee indicated that subtopics to be incorporated in lesson plans included amongst others the topic of the lesson, the duration of the lesson, learner and teacher activities as well as resources.

Although the teachers observed claimed that they used OBE strategies, these were not clearly evident in the lessons observed. The classrooms were not planned for OBE teaching. Desks were arranged for group work although the teachers demonstrated little knowledge of the strategy. Group activity was made up of all members of the group reading from one text or observing and looking at objects from one source. One learner then gave a report from the group’s discussions. In two the classes the learners gave a report without the teacher writing a board summary or giving a comment. It was however, possible for the learners to work in pairs and individually.

In the first lesson observed, the learners were passive. The teacher did most of the talking. Even when they were asked to discuss the chemistry concepts, the majority did not say anything.

During one lesson students discussed fund- raising activities instead. In lessons two and three, the learners were actively involved. The teachers continued to distribute questions evenly and this made learners take part in the lesson. There were however, no hands-on activities. In lesson four learners worked in silence. They had been given some exercises to do. Lesson two involved a lot of problem solving put on the board by the teacher. In lessons three and four, the learners had to recall content. For example, in lesson three learners had to remember the different symbols of elements. In lesson four they had to recall Ohm’s law. In other words, questions were of the recall type.

Assessment practice
The responses of the participants on assessment practice showed that only 50% of the respondents used assessment plans. 80% of them however, followed assessment programmes as laid down by the department but only 50% provided learners with these programmes. The assessment forms used included class work -90%, assignments - 90%. 75% of the rural teachers gave their learners home work while all 100% urban teachers did that. All the teachers gave tests, case studies, investigations, demonstrations and projects. The urban teachers said they involved their learners in experiments. All the teachers used examinations. The teachers also claimed they used a variety of verbs in the higher cognitive levels in asking questions.

In the lessons observed, no practical work was performed. In all schools there was a semblance of a laboratory because even though rooms had been designated as laboratories, they were almost empty. There were no chemicals and very few apparatus. There were no charts or pictures of scientific of
Teacher support and development
On teacher development, 75% of the urban respondents said they had qualifications in OBE methods while only 50% rural teachers said so. 90% of both urban and rural respondents said their knowledge on OBE was from workshops organised by the Department of Education and from discussions with colleagues (80%). While all the urban teachers said they were often visited by subject specialists only 40% rural respondents said they received such visits.

When asked if they used only prescribed textbooks in their teaching, all the interviewees indicated that they did not rely only on one textbook for information however, the department prescribed textbooks for use. One indicated that different text books were consulted. The two urban educators indicated that they used the internet as well. On the other hand one respondent indicated that sometimes one had to use one’s own money to use the internet to get information for the learners. Magazines, as one respondent said, were also used to get information.

On Practical work, three of the four interviewees said use of practical work in Science teaching was very difficult because of lack of resources. There were no apparatus and chemicals at schools. They however indicated that whenever possible, they improvised.

Problems faced by teachers
The respondents listed the following as some of the problems they faced in implementing the curriculum, over-crowded classrooms, lack of teaching and learning resources, lots of paper work for educators, irrelevant context of textbooks to the learners’ environment, and learners difficulties in understanding science concepts. The teachers also cited absenteeism among learners, lack of parental involvement, lack of regular workshops by subject advisors, learners’ negative attitude towards science, lack of some textbooks to cover all the LOs and ASs for Senior Phase Natural Sciences, lack of libraries and internet facilities.

Suggestions to overcome challenges faced by teachers
To overcome the challenges that teachers faced regarding the implementation of the NCS in science teaching, the respondents suggested the following:
• The number of learners in classes should be reduced.
• Paper-work for teachers should be reduced.
• The Department of Education should supply disadvantaged schools with resources.
• The context of textbooks should not be too abstract.
• Subject advisors should conduct workshops for teachers on a regular basis.
• Schools should be provided with computers and Internet services.

The teachers said teacher support groups should be formed, teachers should be given bursaries to further their studies, schools should be supplied with resources, and teachers should improvise whenever necessary when it came to practical work. Above all they said, teachers should be given orientation on the introduction of new curricular.

Discussions
Perceptions based on location of school
Teachers’ perceptions towards the implementation of the Natural Sciences curriculum of the NCS were the same for all schools. Each school was supplied with the curriculum document but its implementation was affected as to whether a school was rural or urban, number of learners per class
and educators. OBE as a policy was independent of the location of the school, number of learners, classes and educators. Teacher did not simply know how to apply OBE in teaching.

**Teaching and learning support**

It was evident that apart from the curriculum document other teaching and learning support materials were not available. Schools in rural areas for instance did not have laboratories. So called laboratories in some urban areas were almost empty. Only chairs and tables were available. It was established however, that the teachers needed further education and or continuous in-service to be informed of new trends or to be taught about different strategies for teaching. The situation in schools made improvisation ineffective. About 60% of the respondents did not use the laboratory. Rural schools had no electricity to facilitate laboratory work. It was found that more than 85% of the educators used and followed the NCS policy documents only. This did not augur well for effective teacher role.

**Lesson preparation and presentation**

It was noticed that 95% of the teachers followed the three levels of lesson planning; consultation of the learning programme followed by aligning this with the work schedule and then formulation of lesson plan. Even though teachers’ knowledge of OBE was lacking the lesson plans had outcomes and assessment standards. However, it was also noticed that educators copied Learning Outcomes and Assessment Standards as they appeared in the NCS document or the textbook without any adaptation. It was also found that most of the teachers used the template from their Area Project Offices for writing lesson plans. Even though lesson plans included LOs, observations of lessons indicated that educators did not know how to teach to achieve those LOs. Even though educators’ lesson plans followed the official format, lesson presentations did not follow OBE principles. Educators however, followed OBE and constructivist principles in practicing group work albeit not from their understanding of the principles. 75% of the respondents indicated that all the lessons were built on the learners’ prior knowledge. This was also evident during observations. All the educators observed started from the known to the unknown.

The characteristics of the teachers to offer help to learners in their groups is in line with the characteristics of the constructivist teacher who is a facilitator and is one of the many resources that the learner may learn from, not the primary source of information (Brook and Brooks, 1993 cited by Hanley, 1994: online). It was encouraging to note that the respondents gave learners a chance to report back. This made learners feel like they owned the subject. The inability of the teachers to explain the outcomes to be achieved was against OBE principles. Lesson presentation on the whole, differed from place to place and according to how experienced the educator was.

**Teaching strategies**

More than 80% of the participants used group work, whole class discussion, problem solving, cooperative learning, experimentation, work sheets, projects and presentations as teaching strategies. These methods are highly encouraged in learner centred teaching. Only 47.5% of the respondents indicated that they still used the telling method. This is a clear indication that teachers in this study were doing away with the traditional teacher - centred way of teaching.

It was observed however, that two of the four educators still read from textbooks and learner exercises came directly from the textbooks.

**Assessment practice**

According to the DoE (DoE, 2002a) teachers are, compelled to apply different assessment strategies and tools in their teaching. To this end more than 80% of the respondents indicated that they used class work, assignment, homework, tests, examinations, investigations, demonstrations,
projects and observations, as assessment tools. It was however, not evident that all the assessment strategies mentioned were used by the educators. Questions educators asked during lessons were mostly low order questions. Some educators also did not allow learners “wait time” to think and answer questions.

Teacher support and development
Although teachers were supposed to teach using OBE methods it was evident that their knowledge on this principle was limited. The educator responses indicated that they needed support in order to implement the NCS in a number of ways. This assertion is supported by the fact that almost all the teachers (95%) indicated that their knowledge of OBE was from workshops organised by the Department. About 90% of the teachers engaged in discussions on the implementation of the NCS with colleagues. One teacher indicated during the interview that “OBE should be done away with because it has too much work”. Workshops organised by the Department were insufficient and lacked content detail. Workshop presenters, mostly departmental representatives and subject specialists only passed on official information. Educators’ knowledge about OBE was based on such workshops. Suggestions were that tertiary institutions must be involved in training teachers.

Problems of NCS implementation in schools
Problems which the educators faced included lack of resources, over-crowding, learner absenteeism, inadequate teacher qualifications, incompetence in the medium of instruction, lack of discipline among learners, etc. These were problems for which answers were sought. It appears that teachers were not completely empowered to play active roles in the process of implementation

Conclusion
It is evident from the discussions above that although the teachers were doing their best they lacked background knowledge in the application of OBE principles in teaching. They lacked expertise in the application of alternate strategies. The teachers followed departmental guidelines in a mechanical way. Most of them continued to read from textbooks. They were overwhelmed by the amount of work they did and they had little or no experience in paying individual attention to learners. In short the majority still practised teacher –centred teaching. They lacked the necessary support to make their work successful.

The overall finding of the research is that teacher roles are not satisfactory due to a multitude of factors. These ranged from internal as well as external factors.

Recommendations
The following recommendations are made based on the findings and conclusions.
School laboratories: It is recommended that the Department of Education should provide sufficient budget for the provision of laboratories, especially in the rural areas. Alternatively, schools should try to buy some basic chemicals and apparatus.

In-service education and training
The Department of Education, Universities and Non-Governmental Organisations (NGOs) must take part in providing in-service training and education for teachers. It is recommended that in-service training should target teachers’ content, methods including laboratory training and assessment strategies. Tertiary Institutions must offer programmes in the implementation of the curriculum. Teachers must be awarded certificates after attending workshops, in order to motivate them. The workshops held should last five days or more to allow more areas to be covered. After workshops,
teachers should be visited and supported in schools to implement what they learnt. Teachers can be funded to pursue their education in universities.

**Installation of internet in schools**

There is a serious need for the internet to be installed in schools. This would help educators and learners to move with the times, and access information.

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Teachers as promoters of Environmental Education: A case study of three Lesotho schools

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Abstract
This article reports on an investigation aimed at finding out how Junior Secondary science teachers promote Environmental Education. The purpose of the study was to find out how teachers implement the National Curriculum with regard to Environmental Education. The framework used to analyse how teachers implemented the curriculum was teaching about, in and for the environment. The research questions underpinning the study were: How do teachers implement the curriculum to promote environmental learning and why do they implement the curriculum in the way they do? The methodology used was interpretive as teachers were observed closely as they taught lessons on the environment. This was followed by in-depth interviews in an effort to understand teachers’ reasons for teaching as they did. The results show that teachers mainly teach about the environment; never in the environment and seldom engage learners’ in activities where they could develop positive attitudes activating them to act for the environment. Teachers justified their actions by providing a number of reasons why it was not feasible to teach in or for the environment. This has implications for the promotion of Environmental Education in Lesotho schools.

Introduction
Lesotho faces numerous environmental problems. The education system is seen as a vehicle for promoting environmental literacy. The Curriculum and Assessment Policy Framework (2008) advocates curriculum integration to effectively address challenges and issues facing the nation. The inclusion of environmental issues in a number of subjects aims at equipping learners with competencies necessary to address such issues. The responsibility of delivering this intended curriculum lies with the teachers. This study is part of a larger study which seeks to determine what the link is between the intended, implemented and attained curriculum and how this links facilitates environmental learning. The aspect of curriculum that is the focus of this study is the implemented curriculum. Research was conducted to determine how teachers implement the curriculum with regard to Environmental Education. The research aims to determine how the pedagogy of science teachers’ in the junior secondary phase of education promotes Environmental Education. The research questions that guided the study are:

- How do teachers implement the curriculum to promote environmental learning and
- Why do they implement the curriculum in the way they do?

Literature Review and conceptual framework
Implementation of the curriculum
Curriculum is defined differently by different researchers. Stenhouse (1989) identifies two categories: One category defines curriculum as a plan that tends to prescribe what should happen in schools, referred to as the intended curriculum by Aikenhead (2006a). The second category views curriculum as what is actually happening in schools, regardless of whether or not it is planned, described as the
implemented curriculum (instructional practice).

Both the above definitions do not identify that aspect of the curriculum which is the attained curriculum or learned curriculum (the content learners have actually learned), the third form of curriculum suggested by Aikenhead, (2006a, 2006b) and Van den Akker (1998).

According to Mills & Tregust (2002) there are four aspects of curriculum that may be defined as follows: The intended curriculum is the original vision underlying the curriculum in the form of the stated objectives or curriculum theory, the implemented curriculum is the actual instructional process as implemented, the perceived curriculum is the actual learning experiences as perceived and/or experienced by the learners and the achieved curriculum is the resulting learning outcomes of the learners. Both the perceived and the implemented can be taken as one because they are actual processes in the classrooms.

Universally, in planning a curriculum, curriculum developers assume that the instruction learners receive in the classroom translates into their learning. Similarly environmental education assumes that learning about environmental issues has the potential to change learners’ attitudes and behaviours toward the environment. An abundance of research into the way learners learn has demonstrated that this may not be the case and learners may not be attaining the intended curriculum (Hewson, 1988). Reasons for the failure of the link between the intended and attained curriculum may occur at the level of the teacher, where the teacher’s knowledge and pedagogy may result in an implemented curriculum that is very different from the intended curriculum.

Teacher knowledge
Rollnick (2008) points out that research into teachers’ subject matter knowledge has recognised that teachers employ much more than the knowledge they have of their subject matter when teaching. She contends that they transform the content knowledge into a form that can be used for teaching and understood by the learners. The transformed knowledge has been described by Shulman (1986) as pedagogic content knowledge (PCK) and is the understanding of content knowledge and appropriate methods of teaching. Rollnick (Ibid) argues that PCK embodies the way teachers engage in the business of teaching their subject by accessing what they know about their subject, the learners they are teaching, the curriculum with which they are working, what they believe to count as good teaching, research findings, and their local context. PCK is an essential part of teachers’ subject matter knowledge and as such this should be evident (or develop) in their classroom practice (Rollnick, 2008). The actual instructional process as implemented during classroom practice is the implemented curriculum which should be in alignment with the intended curriculum as outlined in educational policy. Cutter (2002), however warns that teachers’ knowledge of the content affects both what teachers teach and how they teach so they are likely to emphasise areas they are more knowledgeable and avoid areas in which they have relatively less content knowledge. This would result in non-alignment between the implemented and intended curriculum as well as the attained curriculum.

Pedagogy in African schools
Classroom processes within the African context are characterised as teacher-centred; content-driven; examination-oriented with emphasis on lecturing, note-taking, rote learning and recall; whole class approaches with minimal individual learner involvement and chorus answering as well as strict discipline (Stronkhorst & van den Akker, 2006). In Lesotho teachers claim that learners prefer to learn passively by rote and by chorusing, consistent with relationships and teaching in traditional culture, arising from respect for elders, and beliefs that the child, by virtue of inexperience and limited relationships, should learn ‘from’ the adult (Malcolm, 2003; Polaki & Morobe, 2007). ‘Chalk and talk’ teaching strategies, largely aimed at verbal recall of factual information and definition characterises most African classrooms (Chisholm & Leyendecker, 2008). This has implications for teacher practice.
Jegede and Aikehead (1999) contend that social constructivism characterises the nature of knowledge to include the following five ideas: knowledge is not a passive commodity to be transferred from a teacher to learners, pupils cannot and should not be made to absorb knowledge in a spongy fashion, knowledge cannot exist separate from the knower, learning is a social process mediated by the learner’s environment, and the prior or indigenous knowledge of the learner is of significance in accomplishing the construction of meaning in a new situation. They declare that all learning is mediated by culture and takes place in a social context. The role of the social context is to provide scaffolding for the learner, and provide hints and help that foster co-construction of knowledge while interacting with other members of society (Jegede & Aikenhead, 1999). For learning to be effective, these authors contend that learning should occur within a community of practice.

Concepts pertinent to the study
The concepts discussed below will be used as a lens through which the research is conducted.

Environmental Literacy
le Roux (2000) states that if a socially constructed perspective of environmental issues is adopted, it means that the approach to environmental education programmes should be multidimensional, contextually responsive, relevant, topical and praxis-oriented because such an approach would develop environmental competencies that would enable learners to fulfill the role of social environmental transformers. According to Loubser, Swanepoel and Chacko (2001) Environmental Literacy is essentially the capacity to perceive and interpret the relative health of the environmental systems and to take appropriate action to maintain, restore or improve the health of those systems. To be environmentally literate, a sound knowledge of the threats to our environment is essential. Environmental Literacy involves the development of an ecological conscience, a responsible commitment, attitudes, values and ethics as well as knowledge and skills important in solving environmental problems for the survival of the ecosystems. Therefore, it can be said that Environmental Literacy is in accordance with the five categories of objectives (awareness, knowledge, attitude, skills, and participation) of Environmental Education and the guiding principles of Environmental Education (Loubser et al, 2001).

Learning ‘about’, ‘in’ and ‘for’ the environment
Environmental learning has been identified as having three dimensions: learning about, learning in and learning for the environment. Learning about the environment focuses on key environmental knowledge and understanding of the ecological functioning of the environment. Learning in the environment encourages interactions and experiences in the environment. This enables learners to develop positive attitudes and values towards stewardship of the environment. Learning for the environment focuses on learners taking action for the protection or conservation of the environment. This includes the development of the skills to enable learners to be active and informed participants in the environmental decision-making policy. This is stewardship and action on the environment. (Board of Studies, 2000; Disinger, 1990).

Jenkins states that
perhaps most difficult of all, however, is constructing science courses which will help empower young people as future citizens in ways that existing science courses are widely seen as having failed to do so’ (Jenkins, 1992, p. 243).

He believes that it is essential for students to be engaged in genuine practical reasoning in order to experience science education for action. This means there is a need for a local context or community of
practice to make the experiences genuine, as without this the activity is reduced to its technical
dimensions. The local context also provides the opportunity for generations of local knowledge
informing and empowering action. Environmental Education should therefore have an in the
environment component, an about the environment component and a for the environment component.
These three categories of environmental learning will be used to analyse teachers PCK in the
classroom.

Methodology
The methodological approach to this study is interpretive as we attempted to interpret teacher’
classroom practice. The sample was purposive as three teachers who teach science in the junior
secondary phase were selected to participate in the study. It was also convenience sampling as one of
the researchers is familiar with the schools and the teachers and the selection was done, based on the
topics teachers were teaching at a particular time. We relied heavily on the teachers’ willingness to be
observed as they taught. Three teachers agreed to participate in the study.

Data were collected using the following instruments:
1) Classroom observations: Each teacher was observed several times teaching environmental topics.
2) Each teacher was interviewed at the conclusion of the classroom observations.

The framework for analysis of the data is teaching about, in and for the environment. The fact that the
topics taught were environmental content was a given. Teacher’s pedagogic strategies were categorized
and analysed according to the three categories above.

Results
The results reported are an analysis of the three teachers’ classroom practice as well as analysis of the
interviews conducted with the teachers.

Classroom observations
All three teachers taught the same topics over a number of days. These were: environmental changes,
pollution, soil erosion and deforestation.

Table 1: The identification of categories and themes in observed classes in which environmental
topics were taught.

<table>
<thead>
<tr>
<th>Themes</th>
<th>Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ntina</td>
</tr>
<tr>
<td>1. Teacher preparation</td>
<td>list of topics to be</td>
</tr>
<tr>
<td></td>
<td>discussed</td>
</tr>
<tr>
<td>2. Teaching strategy</td>
<td>Direct instruction</td>
</tr>
<tr>
<td></td>
<td>Question-Answer</td>
</tr>
<tr>
<td></td>
<td>Learners reading</td>
</tr>
<tr>
<td></td>
<td>Link with other</td>
</tr>
<tr>
<td></td>
<td>lessons other subjects</td>
</tr>
<tr>
<td>3. Questioning</td>
<td>Recall information</td>
</tr>
<tr>
<td></td>
<td>Application</td>
</tr>
<tr>
<td></td>
<td>Everyday knowledge</td>
</tr>
<tr>
<td>4. Use of chalkboard</td>
<td>Write topics</td>
</tr>
<tr>
<td></td>
<td>Write main points</td>
</tr>
<tr>
<td></td>
<td>Write notes</td>
</tr>
<tr>
<td>5. Learners engagement</td>
<td>Learner-learner</td>
</tr>
<tr>
<td>------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>Learner-teacher</td>
<td>Yes</td>
</tr>
<tr>
<td>Learner-content</td>
<td>Reading, copying note</td>
</tr>
<tr>
<td>6. New information</td>
<td>Explain new terms</td>
</tr>
<tr>
<td>7. Monitoring learning</td>
<td>Yes</td>
</tr>
</tbody>
</table>

One teacher had no notes to work from; all she had was a list of topics on a piece of paper, while the other two teachers had more extensive notes. All three teachers relied heavily on direct instruction. Ntina asked learners to read directly from the textbook and where activities were mentioned in the textbook, she told the learner to skip the activity part. All three teachers made use of closed-ended questions that were based on factual recall, such as:

“What is soil erosion?”; “What are the causes of soil erosion?”

Questions served to focus on the lesson purpose. When learners gave incorrect responses, teachers would attempt to clarify their understanding by explaining in more depth. The chalkboard was used to write topics and main points during the lessons and to focus learners’ attention on important issues for example: Soil erosion: causes and prevention and Pollution

Learners’ everyday knowledge was sometimes used, for example the teacher referred to collect-a-can which was familiar to all of them; this developed into a class discussion of what happens to the cans. Another class was asked to provide examples of things that pollute land in their environment and the responses were:

“papers, dust in the classrooms, tins, peels, plastics, bottles, and boxes.”

This teacher explained how the named pollutants pollute and during the explanations there were several simple recall questions asked and the learners responded appropriately. Few opportunities arose for learners to apply knowledge. One teacher expanded the notion of environment to include the social aspects of the environment. One teacher promised to take learners on an outing to observe recycling projects.

All the lessons were aimed at developing knowledge with regard to the environment. There was little opportunity for learners’ to discuss environmental issues or to engage in problem-solving activities. The dominant pedagogy was teacher talk and question-and-answer interaction. Teachers did not see the necessity for doing any out-of-school activities which might encourage attitudes with regard to acting for the environment. All the lessons may therefore be classified as lessons where learners learn about the environment. No opportunity to learn in or for the environment arose. Although one teacher promised to take learners on a visit to a recycling facility, it was obvious that the teacher did not view such an activity as an alternative way of learning and as valid as classroom-based learning.

**Interviews**

Teachers’ interviews were conducted after lessons in an attempt to understand their reasons for teaching in the way that they did. Themes were extracted from their explanations and analysed to determine factors that influenced their choices in teaching about, in and for the environment. The following themes were identified:

**Time**

Time was a factor of constraint identified by all teachers as a constraint. For example when Ntina was asked why she decided to read instead of visiting eroded places as suggested in the book, she responded as follows:
“The time (40 minutes) was too short for a field trip. Apart from that learners were familiar with eroded places, so there was no need of visiting such places. Also this section was a revision of primary work.”

and

“Teacher talk saved time and did not involve traveling that might interrupt other subjects.”

Over crowded classes
Teachers justified teaching only about the environment because there were too many learners in class. It was easier to manage them in a classroom than outside.

“....... there were too many learners and they would be out of order.”

Reading in class by one learner and others listening was valuable as every learner would be concentrating on one issue at the same time.

Familiarity with the environment
Teachers did not teach in environment because they said that learners observe daily the environmental problems:

“Learners are familiar with these polluted places. They mentioned the solutions to such environmental problems as they did in class.”

and

“Learners see pollution every day, they know it so there was no need of taking them to such places. When asked questions about environmental degradation learners responded correctly.”

Revision of previous work
Teachers said there was no need to teach in and for the environment because the topics soil erosion and pollution were treated at primary level because of the spiral nature of the curriculum. Therefore the work had been covered before.

Examinations
Teachers said they prepared learners for examinations and taught about the environment. One teacher said she used photocopied extracts from past question papers because

“It was a good method for learners. They became familiar with the style of questions and learned correct responses.”

And another said

“The syllabus and examinations required learners to describe in order to pass examinations. Learners were not awarded marks when they collected cans and kept environment clean, or planted trees. If they got marks that way, teachers would change their teaching methods and learners would do it daily and not teach about environment.”

Knowledge first
Teachers felt that in order to act on the environment the first thing is to have knowledge of what is proper and appropriate. One teacher said:

“One has to know first and then do something about what he/she knows.”

She taught about the environment so that learners may act later in life.

Syllabus just a guide not prescription
Bokang taught about environment because the syllabus was a guide and teachers had different strategies of achieving the learning outcomes. She said:

“The syllabus was just a guide not a prescription every teacher achieved the learning outcomes with any teaching strategies and resources available.”
Personal values
One teacher justified teaching about the environment by saying that people have different values. Some may practice what they learned in their life. She said:

“If they value the science they are taught, but people are different and have different values and it depends on individuals, some may learn and live what they have learned some may not learn and value anything.”

Parental involvement
Tefo justified teaching about the environment by saying that parents should be involved in the learning of their children. He said:

“At school teachers taught learners to pass examinations. Parents had to play a role too, together all must aim at developing responsible citizens, and teachers alone cannot achieve that goal. Teachers taught science and parents had to teach proper behaviour towards environment.”

Decontextualised syllabus topics
Teachers justified why they taught only about the environment by giving examples of topics from the syllabus that were inapplicable to the Lesotho context. Bokang was of the view that:

“For some pollutants learners were not in a position to come up with solutions themselves unless they were told. Taking them out would not bring anything new.”

Discussion and conclusion
Both classroom observations and interviews revealed that teachers placed a high premium on factual content. They were of the opinion that learners needed knowledge of the environment more than anything else. Once they had knowledge they would be able to act on the various environmental problems they were faced with. Thus a chalk-and-talk approach dominated their teaching.

The interviews revealed that teachers had priorities other than organising outings for learners. They also held the belief that taking learners into the environment would make very little or no difference as they are aware of problems in their environment. This attitude reveals teachers poor understanding of experiential learning, the point being that learners should not just observe environmental problems, but should engage in activities related to the problem. In this way they not only acquire knowledge of environmental problems and experience alternative ways of learning; they also have a greater chance of developing positive attitudes towards the environment than classroom-based learning provides.

The data also revealed that teachers paid little attention to learning for the environment. They seemed to assume that if they spoke about and informed learners about solutions to environmental problems, learners would know how to solve such problems. The notion that action requires some change in the affective domain is not fully understood. While learners acquire knowledge, but experience no change in their attitudes, no action to solve environmental problems will be taken.

This research brings the need for appropriate environmental learning for teachers to the fore. Until teachers understand fully what it means to learn about, in and for the environment, there is little change that they will be able to promote Environmental Education in Lesotho schools.

References
Learning to be a Scientist: Are Pupils' Classroom and Out of Classroom Experiences Synchronised?

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The attempts to reap the benefits of linking informal and formal learning experiences in the provision of science education in Zimbabwe has been under threat of the persistent use of traditional teaching approaches in science classrooms (Mpofu, 2006). From a constructivist perspective it is this complementary informal/formal experiences facet that presents learners with the opportunity to be actively involved in doing and thinking, in everyday contexts as they learn science (Van Zee & Roberts, 2001). Literature is rich in the motivational factor of the constructivist approach to learning science. The limited use of constructivist approaches in the Zimbabwean science classrooms coupled with the complex nature of science concepts may be explanatory to the ever dwindling numbers of science takers at higher levels. The science enrollment problem is global and degenerating. However, despite these challenges the fact that there are always few students who are unwavering to the challenges is an indication that there is more to understand about the learning of sciences than mere relationship of teaching approach to learning.

As science educators at Bindura University of Science Education, all researchers are involved in teacher education in the course of their professional duties felt the need to conduct a learners’ science experiences focused phenomenological investigation. The rationale of this focus is to get understanding of and insights into learner experiences and their thinking processes as they concede or circumvent to the learning of science challenges regardless of the teaching approach employed. Furthermore the researchers believe that learner focused research is a rather neglected area in recent research studies which mostly focus on teachers. Focusing on the learner experience is critical to understanding them and facilitates the creation of appropriate teacher education methodology courses. Such courses may help teachers to harness on motivation science learning opportunities for their teaching. Essentially, in the long run the peculiarity of majoring in science subject will be regained. The approach may curb the science and technology manpower shortage.

A phenomenological case study design as guided by the qualitative paradigm is used to study experiences the pupils acquire in the learning to be a scientist (LtbSc) Zimbabwe Junior Certificate (ZJC) science syllabus unit lessons, relationship of these experiences to their out of classroom experiences, the relevance of their learning experiences to their everyday lives and purpose of science education in Zimbabwe. Learning to be a scientist is a Zimbabwe Junior Certificate (ZJC) level science curriculum introductory topic. The major goal of the LtbSc unit is to inculcate pupils with science knowledge and process skills and inspire them into pursuing Science Technology and Science Career related fields. The phenomenology case design was chosen for its focus on the individuals who experienced the phenomena (events, situations, experiences or concepts) understudy and their feelings, beliefs and convictions about the phenomena (Cresswell, 2007).

A multiple case approach is adopted in the study where single cases (Yin, 2003; Kumar, 2005) are studied to compare and contrast the participants’ feelings, beliefs and convictions about learning science to capture a holistic picture. Four out of forty five (45) purposively sampled Form 1A pupils at Basil High School (pseudonym) in Mashonaland Central province will participate in this study. The idea in purposive sampling is to select cases that are likely to be information rich, with respect to the
purpose of the study (Borg and Gall; 1996). Basil high school is a government, co-educational mainly
day school located in an area of inhabited by people of average to high economic means. Form 1 pupils
are placed in their classes according to their grade seven public examination result. Form 1A is the best
class of the seven form one classes.

Interviews, pupils’ documents (dairies and their written work books) and observations are the methods
which will be used to collect data. The researchers feel that these methods can provide enough
 triangulation of the individual learning experiences in ways that can enable data collection without the
disturbance of the natural setting of the instructional process during the entire three months duration of
planned field work. Dairies and exercise books will be collected every Friday of the week and
returned on the morning of the subsequent Monday. Data interpretation will involve the in-field and
post-field stages. In-field data analysis involves the use of the constant comparative technique to enable
the researchers to reflect on the data gathering processes and schedule individual interviews and home
visits.

Post-field data analysis involves in engaging in interpretative work to bring out patterns and themes
emerging from the data. The text analysis technique and grounded theory will be employed to formally
identify emerging patterns, themes and construct hypotheses as suggested by the data. An attempt to
give direct evidence from the data will be done through selecting direct interview quotations and or
diary extract. Findings will be represented in a narrative and simple descriptive statistics. The results
will be reported as soon as the study is completed and recommendations made based on the findings.

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Using on-line discussion forum to explore pre-science teachers’ arguments about
their role in developing language in science classrooms

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Teaching and learning takes place in the English language in Botswana throughout the primary,
secondary and tertiary levels of education. While Setswana is the national language, spoken by the
majority of the population, learners are taught and examined in English. English is a second and even a third language to a lot of students. While English should become the language of instruction from Standard Two, Science and Mathematics teachers are encouraged to increase the use of English from Standard One onwards. Yet, research on language and learning increasingly show the complexity of challenges faced by second language learners in science.

The role of language in science learning-teaching settings has increasingly gained prominence in research in science education. Constructivists view language as a means of social interaction where learning results from interpreting new knowledge using the learners’ already existing knowledge. Thus, in the science classroom, knowledge is socially constructed when learners negotiate, validate and communicate their ideas in specific discourse contexts. This deep engagement with ideas is necessary for meaningful learning to take place and requires the skill of argumentation (Tippett, 2009). Argumentation helps to create the necessary environment for learners to externalise their thoughts and it's a possible vehicle for conceptual growth.

Researchers have developed a wide range of online learning environments to support dialogic argumentation among learners (Rollnick, 2000; Prophet and Badede, 2009). This study used an online discussion forum to explore final year preservice biology teachers’ arguments about whether or not they perceive helping students with language problems in science lessons as their responsibility. The Case Study involved 13 pre-service Biology teachers in their fourth year of a Bachelor of Education degree, enrolled in an online course ‘Critical debates in biology education’. The course espouses Toulmin’s argumentation framework to discuss a wide range of topics including, but not limited to, re-framing the teaching experience, the nature of science and the biology curriculum, language and the biology teaching praxis, issues of gender in biology teaching and learning, and assessing students communicative and manipulative skills in biology lessons. These topics are readily amenable to argumentation. This study therefore sought to explore the pre-science teachers’ conceptions of their role in developing language in science lessons. They were asked;

“Do you think it is the responsibility of the science teacher to help students with language problems in science lessons?” and “When teaching science, how would you help students overcome language barriers?”

WebCT discussion forum is asynchronous in that learners have to post their arguments before they can be viewed by others. Participating learners can view all the discussions posted by members of the group. It allows sufficient time for the learner to formulate a well thoughtout argument. It also has a distinct advantage of providing equal opportunities for participation since issues of gender; academic ability and status are not readily noticeable through written scripts (Litosseliti, Marttunen, Laurinen and Salminen, 2005). Student journals (written arguments) are stored and can be accessed anytime later. A dialogic argumentation hierarchy used by Clark and Sampson (2007) was used to evaluate the argument quality of the arguments. This heirachy was considered suitable for this online learning environment because the question posed enabled mutiple and possibly opposing perspectives which could generate extended dialogue among the learners.

The findings of this study show that teachers hold oppositional views about whether or not it is their responsibility to help students with language problems in science lessons. Some teachers are able to generate arguments of high structural and conceptual levels. Although confrontational arguments ensued, consensus was ultimately reached in some arguments.
Secondary school teachers’ perceptions of practical work in biology in the oshana education region

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Abstract

This paper reflects work in progress. It is part of a larger study on secondary school teachers’ perceptions of practical work in Biology in the Oshana education region in Namibia. Eight secondary schools in the Oshana education region were randomly selected from a total of 13 secondary schools to take part in this study. A sample comprising 23 Biology teachers was then chosen purposively from the 8 secondary schools. Through questionnaires and observations this study investigated teachers’ perceptions of practical work in Biology and explored the conditions of the laboratories in the selected schools as well as the presence of essential materials to carry out practical work. It is clear from the results of this study that the majority of the Biology teachers did not have a laboratory specifically dedicated for conducting Biology practicals and carried out their practicals in a common laboratory or classroom. It can also be concluded that teachers were not carrying out practicals in Biology. It can further be concluded that the materials necessary for carrying out practical work were not available in the Biology classrooms.

Introduction

After independence, the Ministry of Education and Culture (MEC) in Namibia introduced a new educational system, aimed at “reviewing inequality and inequity within the education system” (MEC, 1993, p.5). The main aim of the educational system was to equip students with the necessary knowledge, skills and attitudes that could enable them to enter institutions of higher learning in and outside Namibia and meet the country’s social and economic demands.

According to the Ministry of Education (2009), the examiners’ reports on Biology Practical Examination Paper 3 shows that Namibian learners have continued performing poorly countrywide in comparison to Papers 1 and 2. The examiners’ reports further point out that it is clear from the candidates’ answers that only a few schools follow a practical approach to the teaching of Biology.

It was against this background that a qualitative and quantitative study was carried out in order to find out the perceptions of Biology teachers to practical work in selected secondary schools in the Oshana Education Region (OER). The study also sought to find out whether the selected secondary schools in the OER had all the necessary resources needed to conduct meaningful practical lessons in Biology.
This study sought to answer the following research questions:
How do Biology teachers in Oshana Education Region perceive the use of practical work during instruction?
Do Secondary Schools in Oshana education region have all the necessary resources for conducting practical lessons in Biology including the existence of dedicated laboratories?
The findings of this study might contribute to new knowledge that might help change the attitudes of Biology teachers toward practical work. This might result in learners performing well on Paper 3.
Theoretical framework and Literature review
This study is based on the theory of constructivism. Constructivists view learning as an active process whereby learners learn to discover principles, concepts and facts for themselves. The instructor and the learners are equally involved in learning from each other (Woolfolk, 2004). Crawford (1996) indicated that social constructivists, such as Vygotsky, emphasize the importance of the learner being actively involved in the learning process so that he/she can construct his/her own understanding. It is believed that learners with different skills and backgrounds need to collaborate on tasks, such as when they are doing practical work together in order to arrive at a shared understanding of the truth in a specific field.

Ever since experimental science was advocated in the sixteenth century (Klainin, 1995), it has been well accepted that practical or empirical work is the major task of scientists. Learning of science therefore, is seen by most science educators as likely to be more effective if the learner is involved in practical activities and takes an active part in the learning process.

Practical work is used to refer to laboratory activities that include lectures, group experiments, and teacher demonstrations where learners are involved in handling and observing real objects and materials (Millar, Le Marechals, & Tibergnien, 1999). Teachers should therefore provide opportunities for learners to handle materials, observe events, handle observation results and be able to draw conclusions.

Namibia has included a practical work component in the teaching and learning of science. Learners in grade 11 and 12 are expected to do practical work in Physical Science and Biology. In grade 12, learners are assessed on practical skills in Paper 3 which is an alternative to course work in Biology. The inclusion of practical work is clearly stipulated in the Biology syllabus (Ministry of Education, 2009).

The value of practical work has long been recognized at the secondary school level. Many teachers acknowledge the value of learning by doing, rather than just being shown or told (Driver and Braund, 2002, p. 222). If students can be allowed to do practical work in Biology, then this will help them understand the content better, because students learn better by doing, they will remember better something that they have done with their own hands, hence perform better in Paper 3.

The development of teachers’ favourable attitudes toward science has often been listed as one of the important goals of science teaching (Hofstein, 1988). Hofstein notes that students enjoy laboratory work in some courses and that it generally results in positive and improved attitudes toward science and interest in the sciences.

Methodology
This research was situated in both the qualitative and quantitative research paradigms. Qualitative inquiry aids the researcher to find out the views of individuals experiencing a particular phenomenon from their point of view. One of the strengths of the qualitative inquiry is the active role of the researcher with the subjects of the study (Henning and Van Kensburg, 2004). Part of the data in this study was gathered by means of observations. According Strauss and Corbin (1998) observation is a technique normally associated with qualitative methods which involve close contact between the researcher and the research participants.

The quantitative inquiry on the other hand relies on the collection of i.e. numerical data. It relies on collecting data based on precise measurement using structured and validated data collection instruments (Johnson and Christensen, 2008). In this study, the frequency of use of practical work and facilities in schools had been quantified to find out to what extent these hinder the use of practical work in Namibian secondary schools in Biology. The researchers combined the two research designs in this study because they were concerned with understanding the social phenomenon from the participants’ perspectives, by being participant
observers during practical lessons. The researchers were also trying to understand the problem from a quantitative view point, by finding out the practical resources used such as the apparatuses and laboratories available at the selected secondary schools.

The population of this study consisted of all 13 secondary schools in the Oshana Education Region which offered Biology as a subject at Grade 11 and 12 levels. Eight Secondary Schools in the Oshana education region were randomly selected to take part in this study. A sample comprising 23 Biology teachers was then chosen purposively from the 8 secondary schools.

Two research instruments were used to collect data for this study. These were a questionnaire and an observation schedule. Descriptive statistics were used to analyse quantitative data and included frequency tables, graphs and pie charts. Qualitative data were categorised into themes that emerged from the data.

Findings and discussions
The Biology teachers’ perceptions of practical work and the conditions of the laboratories in which they carry out the practical work in Biology in the OER are presented in this section of this paper.

Teachers’ perceptions of practical work
The results in Table 1 show that the Biology teachers in this study were aware of the importance of practical work and what its aims were and why it was necessary in the teaching and learning of Biology.

Table 1. Teachers’ perceptions of practical work in Biology

<table>
<thead>
<tr>
<th>Statement</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practicals prove theory in Biology, and make Biology an interesting subject</td>
<td>6</td>
</tr>
<tr>
<td>Practicals promote learners understanding of the topics better, and stimulate interest in the subject</td>
<td>5</td>
</tr>
<tr>
<td>Practicals yield better results in Biology and prepare learners to answer questions in Paper 3 at the national level</td>
<td>2</td>
</tr>
<tr>
<td>Slow learners understand the content better; master the content through investigations and observations</td>
<td>3</td>
</tr>
<tr>
<td>Learners learn better when they see and touch objects, they don’t forget what they saw, and it reinforces the content</td>
<td>4</td>
</tr>
<tr>
<td>Learners develop skills on handling and organizing apparatus and materials and following instructions</td>
<td>3</td>
</tr>
</tbody>
</table>

Although the teachers viewed practicals as important in the teaching and learning of Biology, the class observations showed that, only nine (39.1%) of the teachers carried out practical work. The rest of the teachers did not do practical work. Some of the reasons given for not carrying out practicals by the teachers were; “It was time consuming to prepare practicals than teaching lessons”, “Practicals prescribed in the syllabus were not familiar with the teacher”, and “Practicals were frustrating
especially if equipments were not enough”. Even though all 23 Biology teachers indicated that they carried out practical lessons in Biology, only nine (39.1%) of the teachers carried out practical work during observations.

Presence of resources to carry out practical work
Existence of laboratory manual and or materials for carrying out practical work is necessary for successful practical work that will yield desired results. Both teachers and learners need these materials to ensure learning takes place. Accordingly, the Biology teachers were asked to indicate whether these materials existed in their schools for effective carrying out of Biology practicals.

All 23 (100%) of the teachers indicated that their learners did not have a practical manual that could guide their practical work. This was also confirmed during the observations of practical lessons where none of the learners had a laboratory manual. When asked to indicate how they got around the lack of a laboratory manual, the majority of the teachers said that they often prepared handouts for their learners to use during the practical and also that they used textbooks as a guide for the practicals. In fact it was found during practical lesson observations that some teachers were using the syllabus as a guide for practicals.

Conditions of the laboratories
In order to find out the conditions of the place where the Biology teachers carried out practical work in OER, the Biology teachers were asked whether laboratories existed in their schools. Sixteen (69.6%) of the respondents indicated that a laboratory dedicated for the teaching of Biology practicals existed in their schools while seven (30.4%) said they used an ordinary classroom.

With respect to the conditions of the laboratories, the frequency rating is given in Table 2.

Table 2. Conditions of the laboratory for practical work

<table>
<thead>
<tr>
<th>Condition of laboratory</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory was a bit too old without posters to support the practical</td>
<td>2</td>
</tr>
<tr>
<td>Big but empty, it does not have stools for learners to sit on, tables not enough,</td>
<td>2</td>
</tr>
<tr>
<td>learners standing, benches not enough</td>
<td></td>
</tr>
<tr>
<td>Laboratory was in a good condition, with enough benches and chairs for learners</td>
<td>1</td>
</tr>
<tr>
<td>Laboratory was very small and not neat, it was old.</td>
<td>1</td>
</tr>
</tbody>
</table>

The six observed practical lessons took place in most laboratories which were old, dilapidated and as such not conducive for practicals to be carried out. Of the six laboratories only one was conducive for practical work. It is important that the practical learning environment is conducive for learning if teachers and learners are to become interested in practicals.

Conclusions and recommendations
It is clear from the results of this study that the majority of the Biology teachers did not have a laboratory specifically for conducting Biology practicals and carried out their practicals in a common laboratory (used for both Physical Science and Biology) or in their classrooms. Some of the teachers
did not bother to carry out practical work and taught Biology as a completely theoretical subject, which disadvantaged the learners on Paper 3, the alternative to course work paper.

It can also be concluded that teachers were not carrying out practicals in Biology as shown by the fact that only nine (39.1%) of the teachers carried out practical work. They claimed to be doing so, but in actual sense they were no much practical work taking place in those schools.

It can further be concluded that the materials necessary for carrying out practical work were not available in the Biology classrooms. This was evident from the non-availability of practical manuals for learners resulting in the use of teacher hand-outs. This situation needs to be seriously addressed if practical work is to become popular among the learners and the teachers in the OER in Namibia. It is hoped such a situation will result in improved performance in the Grade 12 examinations in the country.

It is imperative that the Ministry of Education seriously address the problem of both lack of laboratory space for the conduct of Biology practicals and the laboratory resources to ensure the conduct of practicals in schools in OER.

Furthermore, the Biology teachers should be encouraged to conduct practical to help the learners grasp the Biological concepts and attain skills and knowledge that will be useful in doing well in Paper3. Most of the teachers responded that their schools did not have a laboratory specifically for conducting Biology practicals. They responded that they carried out their practicals in the common laboratory as well as in their classes.

Biology teachers should be encouraged to borrow materials necessary for conducting practicals from neighbouring schools in cases where their schools do not have the necessary resources for conducting practicals in Biology.

References
Enhancing Life Sciences teachers Pedagogical Content Knowledge (PCK) in well-functioning ecologies of practice

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Theories of adult learning and professional development have taught us that professional development is a shared venture and peer support and local esprit de corps is a driver of change. This project explored ways of home-grown learning that may benefit teachers and their schools. The evidence in our research certainly indicates that there is a place for the notion of ecologies of practice. This ethnographic research aimed at determining how Life Sciences teachers implement the objectives of the curriculum, especially with regard to a learner-centred and activity-based approach. Another aim of the study was to investigate how the teachers function within their respective ecologies of practice with a view to promote continuous professional development. The data collected by means of qualitative methods indicated that most participants make largely use of transmission teaching strategies and that little best practice with regard to ‘science as enquiry’ exists. The study indicated that many participant teachers do not possess the minimum Pedagogical Content Knowledge (PCK) to make quality teaching possible. In this paper we argue that continuous teacher professional development, to enhance teachers’ PCK, could best be facilitated from a platform of a well-functioning ecologies of practice.

Introduction / Background to the study

In 1959 the American Institute of Biological Sciences introduced the Biological Sciences Curriculum Study (BSCS) with the aim to move away from transmission teaching to more ‘science as inquiry’ methods (Hofstein & Luneta, 1982). Britain followed, and introduced the Nuffield Science Teaching Project (Nuffield Foundation, 1966) with similar aims. This also found its way to South Africa which was also characterized by dogmatic lessons where the science teachers explained the lesson content in a very authoritarian way to the learners (Papenfus, 1967). Research during the 1980’s showed that science education was still very teacher-centred and focused on the memorization of facts (De Beer, 1993; Duschl, 1988; Hodson, 1990; Hume and Coll, 2008).

After the democratic elections in 1994, the Department of Education introduced a new curriculum, as well as an outcomes-based approach to teaching and learning. The new curriculum echoed the importance of inquiry-based learning in the natural sciences. A recent report released by the Department of Education (2009) indicates that many teachers do not implement the curriculum in a learner-centred way, and marginalize scientific investigations in favour of transmission learning. This finding corresponds with the research findings of De Beer & Ramnarain (in press), and Petersen and De Beer on Life Sciences teaching. One of the reasons for this state of affairs is that many teachers do not possess the necessary subject knowledge and/or didactical skills.

This qualitative study forms part of a larger research project by the University of Johannesburg which claims that teachers can make a positive difference and that they are instrumental in developing future scientists and mathematicians. However, it is difficult for the individual teacher to act alone. Theories of adult learning and professional learning have taught us that professional development is a shared

194
venture and peer support and local esprit de corps is a driver of change. Through this project, different sub-research studies, explored ways of home-grown learning that may benefit teachers and their schools. The evidence in teacher development and research over the last decade certainly indicates that there is a place for the notion of ecologies of practice proposed by us. In later paragraphs we will elaborate more on this notion.

Theoretical Framework that guided this research

The focus of this research was to identify how Life Sciences teachers implement learner-centred inquiry-based approaches in the classroom, and the challenges they face in this regard. Our experience and research informs us that many teachers do not possess the necessary subject knowledge to effectively teach some of the themes in the curriculum. Our research also clearly indicated that most of the teachers who participated in this study did not dispose of good pedagogical content knowledge (PCK). Rogan (2004) argues that the missing link in effective science education is very often a well-planned professional development programme, and he suggests that curriculum implementation strategies should be within a “Zone of Feasible Innovation” (ZFI). Rogan’s ZFI built on Vygotsky’s “Zone of Proximal Development” (ZPD). In practice it means that curriculum implementation strategies will only be effective when they proceed just in advance of current practice. Professional development programmes will therefore not be successful if the gap between current practice and the desired practice of the teacher is too wide. In this paper we argue and show how the continued professional development of teachers can best be facilitated within well-functioning ecologies of practice, which could fill the gap.

Rogan refers to the construct “Profile of Implementation” as an attempt to understand and express the extent to which the ideals of a curriculum are being put into practice (Rogan & Aldous, 2005). Rogan’s “Profile of Implementation” describes different levels incorporating four different dimensions with regard to classroom practice. In our research study, we felt it appropriate to introduce a level 0 to this implementation profile, in order to give a more nuanced description of the teachers’ knowledge and skills, and their lack of intent to critically reflect on their own professional development. If a teacher does not become a critical-reflective practitioner, the chances are that this teacher will most likely not ‘move’ to a higher level in Rogan’s profile of implementation. Table 1 briefly summarizes this implementation profile.

Research methodology

This ethnographic study investigated the approaches and problems experienced by Life Sciences teachers in the implementation of a learner-centred, enquiry-based curriculum. Eight Life Sciences teachers in four different high schools in and around Potchefstroom, took part in the investigation. Data was collected over a period of two years. Triangulation, to strengthen the trustworthiness of the study, was performed by tapping into different data sources, namely personal interviews with teachers, observations of their classroom practices and studying artefacts (lesson plans and learners’ workbooks). The transcribed interviews and the field notes of the class visits were coded and analyzed mainly through a deductive approach.
Table 1. Profile of Implementation for Science Teachers (Rogan, 2004). (Please note: Rogan only identifies levels 1 – 4. We find the inclusion of level 0 helpful).

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>CLASSROOM INTERACTION</th>
<th>SCIENCE PRACTICAL WORK</th>
<th>SCIENCE IN SOCIETY</th>
<th>ASSESSMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>o Teacher presents transmission type lesson in an unstructured way and reads mostly from the textbook; o Limited and ineffective media usage. o Learners passive and not always engaged.</td>
<td>o Practical work is seldom done; o Teacher uses limited and not well planned demonstrations to assist in the explanation of concepts.</td>
<td>o Teacher seldom uses examples from the learners’ daily lives, and where used it is very incoherent.</td>
<td>o Written tests on lower cognitive levels. o Tests marked and handed out to learners.</td>
</tr>
<tr>
<td>1</td>
<td>o Teacher presents organized lessons; o Uses textbook effectively; o Learners are engaged and respond to questions.</td>
<td>o Teacher uses classroom demonstrations to help develop concepts.</td>
<td>o Teacher uses examples from everyday life to illustrate scientific concepts.</td>
<td>o Written tests are given. o Most questions of recall type. o Most tests marked and return promptly.</td>
</tr>
<tr>
<td>2</td>
<td>o Textbook used together with other resources; o Engages learners with questions that encourage deeper thinking and meaningful group work.</td>
<td>o Teachers uses demonstrations to promote a limited form of inquiry; o Learners participate in cookery-book practical work.</td>
<td>o Teacher bases lesson on specific problem faced by community.</td>
<td>o Written tests include 50% of higher cognitive questions.</td>
</tr>
<tr>
<td>3</td>
<td>o Teacher structures learning along “best practice” lines; o Learners engage in minds-on learning activities.</td>
<td>o Practical work to encourage learner discovery of information.</td>
<td>o Learners actively investigate the application of science &amp; technology in their own environment.</td>
<td>o Written tests include “guided discovery” type activities; o Assessment includes other forms such as reports.</td>
</tr>
<tr>
<td>4</td>
<td>o Learners take major responsibility for own learning and undertake long-term investigations and o Learners design and do open investigations.</td>
<td>o Learners actively undertake a project in their local community and explore long term</td>
<td>Open investigations and community based projects included in final assessment;</td>
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196
Findings & Discussion

Half a century after the Biological Sciences Curriculum Study alerted South African educators to the need to change from a transmission mode to a context of science as inquiry, very little has been achieved. The status quo remains: transmission teaching in South African science classrooms is alive and well, and remains the daily practice in many of our classrooms. What, where and how did we go wrong?

In this research we identified three of the major challenges, namely: 1) teachers’ lack of pedagogical content knowledge (PCK), 2) the constant curriculum change and the new terminology and jargon of the curriculum, and 3) not well-functioning or supportive communities of practice. Although all these challenges impact negatively on the professional development of teachers, this paper deals mostly with the last one.

We have already mentioned that most of the teachers who took part in this study do not possess good PCK. These findings are summarized in Table 2. Although these findings are not new, it emphasizes the current state in certain Life Sciences classrooms. We used the data in this regard to classify teachers’ PCK skills in terms of Rogan’s “Profile of Implementation” (Table 1) and explained it in terms of his ZFI. This classification of the eight teachers’ who took part in the study is summarized in Table 3. These results were evident in spite of the many teachers’ training sessions/ workshops over the last decade or more. In terms of Rogan’s ZFI we argue that this attempt to teacher’s professional development was unsuccessful because the gap between their current practice and the desired practice was too wide. In this paper we argue just that, and show how the continued professional development of teachers can best be facilitated within well-functioning ecologies of practice. However, we also found that the ecologies of practice under investigation were not functioning optimally to enhance teacher’s professional development. In the next paragraphs we explore this matter in more depth.
<table>
<thead>
<tr>
<th>Teacher</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tbody>
<tr>
<td>Level of PCK</td>
<td>Content Knowledge</td>
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<td></td>
<td>Inadequate-an offhand reading from the textbook without any real engagement by learners; the teacher does not clarify concepts, neither does she really engage with learners’ questions.</td>
<td>Very good subject knowledge. Good interaction with learners, and evidence of more critical engagement with the subject content. Learners actively participate in lesson.</td>
<td>Of a very high standard. Good interaction with learners, and evidence of more critical engagement with the subject content. Where the teacher explained concepts, many factual errors were made. (Examples provided in the text).</td>
<td>Inadequate-an offhand reading from the textbook; learners quite engaged, but the teacher seems to struggle to often answer learners’ questions.</td>
<td>Of a very high standard. Good interaction with learners, and evidence of more critical engagement with the subject content.</td>
<td>Inadequate-an offhand reading from the textbook; learners quite engaged, but the teacher only clarifies concepts when asked to do so by learners.</td>
<td>Inadequate-an offhand reading from the textbook without any expanding or good explanations to learners’ questions. Many content errors were made by the teacher during the lessons observed.</td>
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</table>
Table 2. Summary of the findings (continue).

<table>
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<tr>
<th>Teacher</th>
<th>A</th>
<th>B</th>
<th>C</th>
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<td>Didactical Knowledge</td>
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<tr>
<td>Inadequate-poor lesson plans/ poor use of media/ limited questioning; mostly “chalk and talk”; weak facilitation of practical’s/ group work (when occasionally done) Rogan level, 0-1.</td>
<td>Good transmission mode teaching; the teacher is good at “chalk and talk”, and effectively uses media. Lesson plans adequate. Questioning techniques adequate. Facilitation of practical’s/ group work boils down to “cooking” activities; if it is done. Inadequate use of enquiry based methods. Rogan level 1-2.</td>
<td>Excellent at “chalk and talk”, lesson plans satisfactory/ efficient use of media and questioning techniques. Inadequate use of practical’s/ group work and a lack of enquiry based methods. Rogan level, 1-2.</td>
<td>Inadequate-poor lesson plans/ poor use of media (only the chalkboard is used). Weak facilitation of practical’s/ group work when occasionally done - best described as recipe-type activities or demonstratio, and no evidence of enquiry-based learning. Rogan, level 0.</td>
<td>Very good at “chalk and talk”, lesson plans adequate/ uninspired use of media; adequate questioning. Facilitation of practical’s/ group work sporadic, and best characterized as cookbook activities, with little evidence of enquiry-based learning. Rogan level 1-2.</td>
<td>Inadequate-poor lesson plans/ unimaginativ use of media (when used)/ mostly “chalk and talk”. No facilitation of practical’s/ group work - the teacher seems to be only focused on theory. Rogan level, 0-1.</td>
<td>Inadequate-poor lesson plans/ limited use of media/ mostly “chalk and talk”. Weak facilitation of practical’s/ group work- mostly demonstratio, and no enquiry-based approaches. Rogan level, 0-1.</td>
<td>Inadequate-poor lesson plans/ restricted use of media/ questioning only done on lower levels in Bloom’s taxonomy. Mostly “chalk and talk”; no practical work is done whatsoever. Rogan, level 0.</td>
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</table>
Table 3. Profile of Implementation for Life Science Teachers (According to Rogan’s levels 1-4 and the authors’ level 0).

<table>
<thead>
<tr>
<th>LEVEL</th>
<th>SCIENCE PRACTICAL WORK</th>
<th>CLASSROOM INTERACTION</th>
<th>SCIENCE IN SOCIETY</th>
<th>ASSESSMENT</th>
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<tbody>
<tr>
<td>0</td>
<td>1 2 3 4</td>
<td>0 1 2 3 4</td>
<td>0 1 2 3 4</td>
<td>0 1 2 3 4</td>
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<tr>
<td>RESPONDENTS</td>
<td>Me A</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<td></td>
<td>Me B</td>
<td>x</td>
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<td>Me C</td>
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<td>Me F</td>
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<td>Me H</td>
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Professional development within ecologies of practice

Research shows that occasional and detached workshops have limited impact on teachers’ classroom practices and professional development. Rogan (2004) is of the opinion that professional development should best take place within well-functioning communities of practice. For the purpose of this study, we distinguish between communities- and ecologies of practice (Figure 1):

- A community of practice (CoP) refers to the activity system in a particular school, and how teacher education and professional development resulting from initiatives by the management team, but also professional association between science teachers (as colleagues), are achieved;

- An ecology of practice (EoP) refers to the professional associations of teachers, from different schools in an area, who are all part of a particular cluster.

The eight teachers who participated in this research project have mixed feelings with regard to whether their own schools (CoP), or the cluster group (EoP), serves as a useful platform to enhance their continuous professional development. In the case of the communities of practice at their different schools (CoP) they support each other mostly with regard to administrative tasks and not for professional developmental purposes. Within the cluster meetings (EoP) some of them experience the meetings for assessment not as useful as the meetings/workshops on training. They all have high regard for their subject adviser for the empowering training about new subject content knowledge.
In this paper we use Nardi and O’Day’s (1999) definition that describes information ecologies as a frame of reference to compare our findings:

An (information) ecology is a complex system of parts and relationships. It exhibits diversity and experiences continual evolution. Different parts of an ecology coevolve, changing together according to the relationships in the system. Several keystone species necessary to the survival of the ecology are present. Ecologies have a sense of locality.

We found that the ecologies of practice in our study contain all these elements that Nardi and O’Day (1999) refer to, but that its functionality leaves much to be desired. In the context of this study, we therefore refer to such less functional communities or ecologies of practice as pseudo-communities or pseudo-ecologies of practice (Whitelaw, 2008).

Figure 2 is a summary of the findings of the EoP, based on the five elements of Nardi and O’Day’s definition.

Figure 1. Relation between Ecologies- and Communities of practice.
The small activity systems represent the different schools (= CoP). The interaction between the schools is represented through the arrows. The large activity system represents the cluster (EoP).
We argue that one possible reason for pseudo-communities/ecologies of practice is the tensions within the activity system(s) of a school(s)/cluster(s).

**Recommendation**

This study was structured on the assumption that teachers can make a positive difference. Therefore some of the positive findings were the fact that all teachers are in possession of at least a three year teacher’s diploma and display a positive attitude towards their work. They apply questioning techniques with relative success. The schools where these teachers are located comply with the minimum facilities and sources. The EoP contains all the elements of a functional EoP and that the subject adviser in this cluster can be regarded as a keystone species. This can be the starting point in developing a well-functioning EoP as a platform for teachers’ continual professional development. In the next paragraphs we will discuss the role of the EoP and teacher’s a three year developmental programme (TDP).

According to Nardi and O’Day (1999) all well-functioning ecologies must have a keystone species necessary for the survival of the ecology. The functions of such a keystone species, amongst others, is to facilitate the ecology, identify challenges, create a
safe environment conducive for teaching and learning, is somebody who applies best practices and continually critically reflects on his/her own practice. We are of the opinion that a subject adviser can fulfil such a role especially from the beginning until a well-functioning ecology of practice is established. It is of the utmost importance that more participants in the ecology must be developed into new keystone species in order to lead the community of practice at his/her school, but also to play a leading role in the cluster in the absence of a subject adviser. The EoP can also serve as a platform for induction purposes for novice teachers. As teachers become more competent they can leave the EoP and new, less competent teachers can join the EoP. This will result in a dynamic and sustainable EoP.

We propose a TDP, running over a period of three years, and which is context specific to cater for the individual needs of Life Sciences teachers in order to enhance their PCK. The proposed in-service TDP can be done as an action research project the results of which can be evaluated over the three years period and beyond. Of course, the practical feasibility and available sources must be taken into account.

The following theories or existing programmes were used as the theoretical framework for the TDP (Table 4).

- Vygotsky’s insights into social learning, and emerging CHAT (Cultural Historical Activity Theory): An important aspect of CHAT is the fact that human activity is culturally bounded and that learning, in nature, is a social activity.
- Engeström’s activity system: The TDP can be represented as an activity system.
- Rogan’s Profile of Implementation.
- Kurt Lewin’s Change Theory.
- Giddens Theory of structuration.
- Bell & Gilbert’s Holistic teacher’s developmental program.

Phase 1- The pre-developmental stage

The primary purpose of this phase is to identify and understand the actual needs of teachers (observation that focuses on gaining understanding and insight, rather than on judgment and interventions). In terms of Giddens’ (1984) theory, it implies that the teachers’ existing levels of agency can be determined as well as all the structures (rules, policies, facilities, sources) that have an influence on their agency to render quality education. It also builds on the unfreezing phase of Lewin’s change theory which implies that teachers need to be prepared for the envisioned change. According to Lewin it can only happen if teachers realized the need for change (Burnes, 2004; Change-Management-Coach.com; Schein, 1996). In terms of the professional development component of the Bell & Gilbert program, it means that the teacher experiences certain aspects of his/her teaching as problematic (Bell & Gilbert, 1994). The information gathered in this needs pre-developmental phase will be used to classify the teachers PCK according to Rogan’s Profile of Implementation levels 1-4, and the author’s level 0.
Simultaneously or concurrently the cluster of Life Sciences teachers needs to get ready to function. During this phase the members of the EoP need to identify a suitable venue which is easily available and accessible, contains an equipped laboratory/classroom and teaching media. This venue must be their “safe haven” for the next three years. We propose that the subject adviser will in some instances be in a favourable position to perform this role.

Table 4. Three year teachers developmental programme.

Phase 2- The developmental stage

In this phase the teachers’ PCK will be developed (agency) and builds on Lewin’s transformation phase and where, according to Bell & Gilbert, the teacher’s professional- and social development can take place. We propose that it can be done in continuous reflection cycles (figure 3).

The foundation of this phase is the teacher’s reflective practices while curriculum content and suitable methodologies should be addressed simultaneously. Since the TDP will run over three years, a teacher can be developed alternately and respectively in grades 10-12 curriculum content. During the first year teachers will be empowered on Rogan’s level 1
skills and values. Depending on the performance of the individual teachers, the second year can focus on Rogan’s level 2 skills and values. The third year can be used to consolidate the levels 1 and 2 skills. A teacher needs to enter the programme for the grade they are currently teaching that year. Although we can anticipate certain logistical challenges, it does not mean that all the teachers need to start with grade 10 work in the first year. The aim is to develop teachers that will be competent in teaching any of these three grades in the FET phase.

In the following discussion we will explain the process of one reflection cycle (Figure 3).

**Figure 3. Reflection cycle**

- **Workshop 1:** This can be regarded as the first opportunity where the Life Sciences teachers’ meet each other as an EoP to start the TDP. During this workshop a particular theme, according to the year planner, is chosen. The facilitator will lead the discussion and with the participating teachers appropriate teaching method(s) will be chosen. The pros and cons of such a teaching method(s) will also be discussed, as well as possible difficult content. Attention may also be given to appropriate teaching and learning opportunities that can be designed and how the content can be linked to real-life situations.
• Planning and Reflection FOR Action: With the knowledge and skills acquired during their first working session(s), the teachers’ have to design their own individual lesson plan(s). Planning includes amongst others: the completion of a lesson plan(s), choosing appropriate teaching aids, the design or selection of suitable learning materials, such as a worksheet and so on.

• Application and Reflection In Action: This is the stage when individual teachers conduct the planned lessons and simultaneously reflect (reflection in action) during the course of the lesson. This will be done at their respective schools in a supportive CoP.

• Workshop 2 and Reflection AFTER Action: The second workshop mainly deals with the conduction of the first lessons, it is reflection AFTER action. During this workshop, teachers will be given the opportunity to share their own critical reflections of their own experiences. Suggestions and best practices can be identified and exchanged which can be of use in other appropriate situations in their CoP. If it happens that a teacher realizes that he/she has a particular teaching method or knowledge not yet mastered, he/she can re-plan and apply it again in the next lesson. If all goes well, he/she can proceed to the next cycle to tackle the next theme in the curriculum.

Phase 3- The post-developmental stage

This is the consolidation phase, or the refreezing phase according to Lewin. The boundary between the second and third phase is very vague since it take place continuously and alternately. Skills development of levels 3 and 4 of Rogan’s Profile of Implementation can be the goal for future continuous development in the EoP.

Teachers will be encouraged to keep a reflective journal as a hands-on tool to make their development more tangible and concrete which can serve as intrinsic motivation and as a future reference source.

Phases 1 to 3 are a cyclic process during which the following skills, knowledge and values can be developed:
• reflective practices are developed;
• their agency with regard to their PCK;
• they reach the third level of Bell & Gilberts personal development where they get a feeling of empowerment (I can);

• they reach the second and third levels of Bell & Gilberts social development where they value and initiate collaborative ways of working.
Conclusion

Although the current state of education in SA seems very bleak, we are of the opinion that the situation is reversible. With hard work, dedication, tenacity and a well-thought out in-service teachers development plan much can be done to render quality education to all learners, as entrenched in our Constitution. We believe that our TDP can make a modest contribution in this regard by engaging teachers in reflective practice and developing their PCK.

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The champion in every one of us: Empowering rural communities through ICT

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Abstract

There has been an increasing interest in technology and ICT over the past decade in the rural school communities of South Africa. Finding ways to bridge the technology gap will always remain a challenge even though new technologies arise on the modern front. The study focuses primarily on the impact of the “champion” and the support role he/she plays in the teacher professional development in computer literacy in deep rural areas of the Eastern Cape. This study focuses on measures of champion behaviour and team leadership to enable teachers in collegial clusters in becoming computer literate. Schon (1963) initiated the study of championing. He found that innovation was more successful.
if a champion promoted it. Therefore a champion can be seen as someone who has the
ability to overcome challenging circumstances with the support of a team by working
towards a common goal.

The study is concerned with the need of ICT integration with teaching in schools as well
the role that ICT educators play in transforming the minds of novice users and learners to
educate them about the vital importance of tapping into technology no matter their age,
beliefs or diverse backgrounds. Furthermore the ICT Professional Development Training
model is explained on how the RUMEP (Rhodes University Mathematics Education
Project) MathsNet project undergoes stages of ICT learning whereby key players such as
learners, teachers and the RUMEP ICT coordinator built relationships as a means to
support education through technology as a new avenue to bridge the digital divide in
teaching and instructional learning.

The paper further describes the MathsNet project as a case study to illustrate the effect
educational outreach programmes can have on teachers who sacrifice resources and time
to participate in computer training and support. The aim is to develop disadvantaged
teachers professionally, connect them to the outside technological revolutionary world
and educate them to become computer literate to, in turn integrate technology in their
prospective communities. These communities are known as collegial clusters which are
groups of individuals from a distinct school areas working closely together to reach a
desired goal.

In addition to the champions initiative, a computer literacy short course is introduced to
measure the ITC competence of teachers who participate in ongoing training throughout
the year as they became the inspiration for those teachers who now realised the positive
impact ITC can have in as a tool to support teaching and learning in the classroom.

Introduction

Technology serves teaching and learning best when educators have clear goals. Educators
have the responsibility to teach learners critical skills and ways of reasoning needed for
success in a technological rich environment. Educators are also to encouraged develop
themselves to take advantage of the potential of technology to help learners to meet new
expectations of the digital society.

Education systems in South Africa can be improved by information technology tools such
as Smartboards and web-based learning to name a few. Teachers can use information
technology to create a new set of tasks which negate the opportunities for quality education. A typical example to support the above mentioned statement can be: Teachers have to calculate test averages, percentages and totals for various grades. The traditional way of calculating these figures is time-consuming using a pocket calculator. The solution to this challenge is to introduce the teachers to spreadsheets and teach them formulas and functions. Within no time these worksheets can be developed, printed and presented in a elegant and yet professional format. Even the graphical representation of data in the form of graphs can make interpretation of figures easy to understand.

Schon (1963) states that a new idea either finds a champion or dies. I will use this statement to explain how the MathsNet project addresses the concerns of information sharing and computer literacy skills development by mathematics teachers can improve the quality of teaching in schools. Today’s technology standards encourage teacher education programmes like the MathsNet project to address the need of producing computer literate educators who are not only knowledgeable about the Internet, but also confident to incorporate instructional learning in their every day classroom environment. Unfortunately ICT awareness and implementation into schools has not met initial expectations yet. One of the main reasons is the lack of computer competency by teachers and inadequate technology resources in poor rural areas. In contrast Creighton (2003) points out that even the best schools have barely tapped into the potential of technology to radically impact teaching and learning. Integrating ICT into the education curriculum across the nation can radically narrow the gap between technology-rich and poor. Technology skills development goes far beyond purchasing hardware and software. Technology integration and teaching complement each other but cannot succeed in the absence of technology leadership. Therefore ICT champions in this programme take responsibility to develop teachers in their distinct education environment. Vital computer skills can improve the quality of education from teachers to learners in the classroom.

Definition of terms

To better understand the scope of the study, the following concepts need to be defined.

Table 1. Definitions of terms used in the paper.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Champion</td>
<td>Champions are individuals who emerge to take creative ideas and bring them to life and who ‘actively and enthusiastically promote the innovation, building support, overcoming resistance, and ensuring that the innovation is implemented (Howell &amp; Higgins, 1990).</td>
</tr>
<tr>
<td>Collegial cluster</td>
<td>A collegial cluster is a group of committed individuals from diverse backgrounds, various schools in a geographical area, working towards the same goal of professionally developing one another in challenging fields of teaching such as Mathematics, Science or Technology etc.</td>
</tr>
<tr>
<td>Computer Literacy</td>
<td>Computer literacy is defined as the knowledge and ability to use computers and related technology efficiently. Computer literacy can also refer to the comfort level someone has with using computer programs and other applications that are associated with computers. Another valuable component of computer literacy knows how computers work and operate (<a href="http://www.wikipedia.com">www.wikipedia.com</a>)</td>
</tr>
<tr>
<td>Information and Communications Technology (ICT)</td>
<td>The growing increasing convergence and integration of computing, electronics and telecommunications, allowing the exchange of messages via telephone, access to information and public debate on several through the Internet, television, radio, video conferencing and delivery of high speed wide band services (Howie, 2005).</td>
</tr>
<tr>
<td>Teacher</td>
<td>In the broadest sense, a teacher can be defined as someone who not only teaches or imparts knowledge, but also most importantly, someone responsible for shaping and moulding the minds and hearts of all those whom they teach.</td>
</tr>
</tbody>
</table>

**Conceptual & Theoretical Framework**

**Champions of change**

Champions can be defined as individuals who emerge to take creative ideas and bring
them to life and who actively and enthusiastically promote the innovation, building support, overcoming resistance, and ensuring that the innovation is implemented (Howell & Higgins, 1990). They also go as far to say that champions can be distinguished from non-champions because they can communicate a clear vision of the innovation, display enthusiasm for the innovation, demonstrate commitment and involve others in supporting it. Rogers (2003) defines a champion as a charismatic individual who throws his or her weight behind an innovation, thus overcoming indifference or resistance that the new idea may provoke in an organisation. Thus champions can increasingly influence the values, principles and activities of people who see the ICT champion as a model of inspiration who share knowledge and skills through a rare skill called computer literacy.

Champions in the educational system can be seen as individuals with leadership roles as principals, deputy principles, head of departments or a teacher who want to make a change in the development of is/her peers. Thus, in order to understand how leaders come to take up the championing role, it is critical to grasp what encourages them to act as champions of new technology. To perform these technology roles well, champions need to have a level of ICT competence so they can be effective implementers of new ICT’s (Slowinski 2003). Bassilier (2003) suggests that ICT competence is a key factor that influences technology leadership behaviours, such as willingness to champion new ICT. Considering the focus of this study my research is compatible with the views above.

Champions often willingly risk their position and reputation to ensure the innovation’s success (Howell, 2005). Champions are also an important part of the innovation process in an organisation (Howell & Higgins, 1990). Experienced champions are essential to the success of large ICT projects. Champions therefore play key roles in advancing or supporting the introduction of new technology into organisations (Neufeld, Dong, Higgins, 2007). However, champions are more often not formally responsible for promoting innovations but become technology champions because they believe in that technology (Howell, 2005). Finally, Howell and Boies (2004) suggest that champions need to understand the technology and how it fits within the broader organisational context to be effective promoters of the innovation. The RUMEP MathsNet programme’s key focus was too train these champions so that they could demonstrate and promote effective innovation.

**Method**

Interview data is a major means of self-presentation projecting part of real-life, is quite robust for life-story research (Linde, 1993). This paper addressed the practice of ICT champions’ leadership through narrative analysis of a technology coordinator who is responsible for implementing school-wide technology training in rural areas of the Eastern Cape, South Africa. Cresswell (2002) describes narrative analysis as a strategy
that recognises the extent to which the stories we tell provide insights about our lived experiences.

Since the technology coordinator has such a good understanding with ICT champions, he used interview techniques to further collect data for this study. Two of the ICT champions were interviewed at the Fort Brown School based on the impact they have made on their peers and learners by integrating technology into their teaching profession. In order for individuals to express their personal experiences, the technology coordinator recorded digital audio interviews for this particular study.

ICT Professional Development Training Model

The role of innovative teachers lead the way for others and are also testing grounds of innovation and change within the education system where technology is often not taken into consideration. The ideological approach of these teachers often offend people but they are the ones who already adopted technology in some way or the other, either through personal use, training workshop, school environment or their community where adequate resources are available. In these teachers one sense the clear vision that they have for the profession and personal development and leadership qualities is noted from the time you engage them in new ideas. Teachers of technology innovation can then be seen as ICT champions. Champions are known to the conditions, strengths and weaknesses of their surrounding communities especially the challenges their colleagues are faced with. As a result communities begin to recognise the vision the champion have in mind and support the mission to be accomplished, which is to empower the disadvantaged state of affairs to face the challenges in an ever-changing digital society.

The ICT Professional development training model in figure 1, illustrates the way forward in education whereby the ICT coordinator trains ITC champions the necessary computer skills and knowledge to enable to become confident. They in turn empower teachers to mould leaders of tomorrow. Throughout the world, technology is the cornerstone to communication, education, business, personal lives that will keep us as a united nation for generations to come. With the help of unique projects such as MathsNet teachers have rapidly recognised the potential and use of technology as a tool that can make traditional style of teaching gradually phase.
Figure 1. The technology development training model

MathsNet Project case study

The teachers in this study consisted out of cluster members at the Fort Brown Primary School, about 30km outside of Grahamstown. The school is considered disadvantaged in
technology implementation in comparison to school in urban areas. The school received minimal grants/funding from government and organizations. For example, the school itself was built by a very well known game reserve because of the learners’ parents being employed by this particular company. In the past and the present government started technology initiatives such as computer labs in the cities but neglected the importance of professional development in farms and rural schools. To counter this problem RUMEP established the MatsNet programme is 2005. The MathsNet project provides computer literacy training spanning over six of the collegial clusters. The ICT training modules covered in the project consist of Introduction to computers, Word processing, Spreadsheets, Presentations, emailing and the Internet where connectivity is installed. These modules are presented in a way that it is relevant to teaching profession.

The RUMEP technology coordinator attempts to narrow the digital divide gap between teachers of this school and those of urban areas. My main objective is to empower teachers in their profession to become a role model and mentor for his/her colleagues who do not realise the importance of technology in the instructional learning environment. Those teachers who participated in computer literacy training later became representatives and leaders of the MathsNet computer literacy project. With support of outside funding for the project, RUMEP were able to provide the Fort Brown cluster with two computers to kick-start the project. In addition, the technology coordinator was able to supplement the existing computers with RUMEP laptops to allow teachers to utilise during computer training sessions. I discovered that a significant number of schools have been supplied with computers by government and telecommunications companies only realise it has not been utilized. Nobody knew how to use these computers for their administrative tasks and those who were ICT competent never shared their skills with peers. Also, if leadership is not present, nobody will have the confidence to emphasise the importance of using technology as a tool for professional development.

Fortunately in the case of the Fort Brown Primary School, the principal was appointed as the ICT champion at the school. Schiller (2003) stated that principals must work collaboratively with the teaching staff to effectively lead the integration of technology in their schools. To lead this integration, they must be trained and continually supported on the use of technology. Innovative leaders in collegial clusters will instantly recognise the potential of ICT in education and will be eager to explore its uses in their profession as teachers in the early stages of the training process. They also automatically make themselves responsible for administrative, training and technical tasks in the absence of the technology coordinator.

In the early stages of the MathsNet project teachers did not share the same active commitment to support individuals who have a clear vision for achieving goals together. Many ICT competent educators did not see the need of attending training sessions where
they could have taken up leadership roles to empower their collegial cluster educators internally. Some educators became resistant against ICT believing it might replace their traditional role as an educator. Other educators were not willing to learn new technologies and want their teaching to stay the same without ICT integration while others were afraid to use computers or similar technologies such as digital cameras and projectors.

A resistant attitude towards professional development mainly develops because of a low level of confidence. The ICT coordinator realised that the lack of strong leadership was a major obstacle to effective technology integration. In the MathsNet project situation, teachers depended entirely on the ICT trainer until next computer workshop will commence. As a result progress was made and the entire vision of the project took a knock because of the lack of continuous training support. As a result in 2009, the ICT championship innovation was introduced. Educators had to select a champion from their perspective collegial clusters to lead the training workshop in the absence of the ICT coordinator, who conducts training at various collegial clusters. Gemunden, Salomo & Hulzle (2007) believe that radical innovations cannot become successful without the special backing of highly committed people within a firm. However, even highly motivated educators with enthusiasm can be discouraged by the lack of confidence by their colleagues. This gave rise to introduction of the ICT champion who can be defined as the key to the implementation of technologies and their actions appear directly related to the success or failure of many innovations.

The introduction and integration of ICT in the teachers’ lives have changed their perceptions that technology was only designed for chosen institutions and individuals. In the case of the Fort Brown Primary School, technology has open doors to advanced opportunities as they are currently renovating a room as a computer lab and seek funding for Internet connectivity. As a sign of appreciation and recognition for their work, the very same owner of the game reserve who built the school, also built a teachers’ residence. Since the school is so remote from Grahamstown, teachers have the opportunity to stay on site. This allows them to spend extended time on the computers to complete their desired work in advance and become more accustomed to practice computer literacy skills. MathsNet inspired educators to use ICT for the preparation of tasks that provide early success, to increase their confidence in the classroom and in their daily lives.

Discussion

Teachers’ role in support of championing at schools

The role of ICT in schools has dramatically increased with the mounting importance attached to using technology in the curriculum and in the management of the school.
Successful change and ICT implementation in schools depends on effective leadership, but many school leaders feel overwhelmed by the task of technology implementation as they are often without formal training or experience with ICT (Flanagan & Jacobsen, 2003). School leaders should therefore have a minimum set of technology skills to support their leadership roles. Malope (2006) support this argument by stating that without skill, performance is not possible and without self-efficacy performance may not be attempted. In the modern era I believe computers can transform learning and teaching in schools by helping teachers and learners to use their minds profoundly through creative and critical thinking. Weaknesses in ICT implementations, such as the lack of technology integration in schools, are partly attributed to low ICT competence, which in turn, may be due to inadequate professional development (Brockmeier, 2005).

In the case study with Fort Brown teachers, the following attributes were observed from the ICT champions. Their attributes can be summarised as follow:

- Positive attitude towards ICT
- Ability to manage ICT in the classroom
- Ability to evaluate ICT use in collegial clusters
- Gain confidence to teach ICT literacy to learners
- Ability to ensure progression of ICT skills development
- Understanding the educational potential of ICT

Teacher professional development & ICT

Professional development is a relatively new term (Hoyle, 1985). It’s often seen as merely a synonym for in-service training. It can be defined as follows: It’s a process starting with initial training, followed by exposure to practice and lasting during the whole career, during which the educator seriously attempted to attain and develop addition knowledge and skills need for effective professional practice. Teachers are surrounded by technology. Even if they don’t have access to computers, it can take form via modern gadgets such as cellular phones. For teachers and learners need to understand how to operate computers, instructional training is required. Information technology is of paramount importance to note that ICT begins with an understanding of needs and possibilities for learning and instruction. The elderly generation is trapped in a deceiving perception that technology is designed for the upcoming and younger generation only. Technology is not the challenge or the barrier. The human factor, the mindset remains the greatest barrier to professional development. If the teacher as a human does not know how to use a technology tool, fears it, or misconstrues its uses, it will be used badly or not at all. If the educator perceives the machine (computer) as a master, not as a servant, its potential will never be realised (Burbules & Callister, 2000). Teachers are beginning to recognise that they must teach future leaders and society the technologies that will become a major part of their future. It is evident that teachers of the MathsNet
programme are already doing their bit towards educational change.

To evaluate the ICT competence of teachers in the MathsNet Project, teachers were required to write a Computer Literacy Short Course at Rhodes University as indicated in Figure 2. Thirty educators in total, from six different collegial clusters decided to write the computer literacy course. With a pass rate of 70%, half of these successful graduates included ICT champions as indicated in the grey bars. The black bars indicate non-champions in the form of teachers. This course is similar to the International Drivers Licence a (ICDL) course which consists mainly out of ITC concepts and software programmes such as Word processing, Spreadsheets, PowerPoint presentations, e-mail, the Web.

![Figure 2. Results of the 2009 MathsNet Computer Short Course](image)

Conclusion

Teachers have to find ways to remain qualified in the face of accelerating change with some form of ongoing education and training. To enable the use of ICT more efficiently, choosing training sessions and participating in new developments in order to improve professional development is of vital importance. From this research there is dire need to develop teachers in implementing ICT. Integration into the school environment needs strong leadership and technological resources to support this innovation. Hence ICT champions will spend a great amount of work pioneering the need to have teachers computer literate in our modern society; the greatest obstacle lies with the commitment of teachers themselves. Without this human support integration of technology in education
will not happen. The ICT champion can be the person that takes up the task of teaching his/her colleagues computer programmes at a lower or advanced level in their collegial clusters or schools. The experiences of teachers show that the more technologically adept we become, the more advanced and successful we will be in the near future. Sharing knowledge, skills and resources need to be trained to better the quality and outcomes of education on all levels of learning.

References:


Understanding the Technology Knowledge of Office Data Processing teachers in the context of ICT-based classrooms in FET colleges

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Abstract

In this paper we present an exploration of contemporary issues related to forms of knowledge needed by Office Data Processing (ODP) teachers in the use technology in ICT-based classrooms. The study from which the paper draws focuses on the following three questions:

1. What is the nature of beginning and veteran ODP teachers Technological Pedagogical Content Knowledge (TPCK) in the use of ICT to teach Office Data Processing?
2. What differences exist between beginning and veteran ODP teachers in term of content knowledge and TPK?
3. How can the TPCK conceptual model be modified by analyzing content, pedagogy and technology in ODP ICT-based classroom?

Further Education and Training (FET) colleges in South Africa now have more “access” to new technologies than has been the case a few decades ago. In addition, much investment is being put into and is said to continue put on ICT infrastructure in these colleges where vocational and technology-based courses are being offered for occupational skill development (Beatty, 2001). However, very little knowledge is known about what forms of knowledge and skills are needed by ODP technology teachers for effective classroom instruction and productive student learning. In addition to exploring the forms of knowledge that ODP teachers need for effective teaching, the research on which this paper is based deals with understanding and extending the frameworks that have been used in unpacking teacher knowledge in the past. This is because this research is located primarily in technology, and so a framework for understanding and unpacking knowledge of teachers teaching with the use of technology needs to have a technology dimension. It appears that in the initial framework conceptualization, Lee Shulman did not explicitly discuss technology.
and its relationship to pedagogy and content. Does this mean that this link was considered insignificant? Recent research in the field of education is now attempting to bring specific attention to the technology dimension of teaching and learning by examining how technology interacts with: (1) pedagogy, as Technological Pedagogical Knowledge (TPK), (2) content, as Technological Content Knowledge (TCK), and (3) jointly as Technological Pedagogical Content Knowledge (TPCK) (Mishra & Koehler, 2005). The research being proposed draws from the TPCK framework, and reviews the relevance of this TPCK framework for understanding and unpacking ODP teachers’ knowledge within the context of ICT-based classrooms in selected colleges. Data sources for this study will include classroom observations for selected ODP lessons, document analysis of ODP course materials and curricula, reflective interviews with teachers, and student study documents and resources. By involving both beginning and veteran teachers in the study, the aim will be to determine differences and similarities in their knowledge of ODP, and how the knowledge differences and similarities are linked to the teachers’ use or non-use and understanding of technology in ICT-based classroom.

Introduction
Further Education and Training (FET) colleges in South Africa now have more “access” to new technologies than has been the case a few decades ago. In addition, much investment is being put into and is said to continue put on ICT infrastructure in these colleges where vocational and technology-based courses are being offered for occupational skill development (Beatty, 2001). However, very little knowledge is known about what forms of knowledge and skills are needed by ODP technology teachers in and ICT-based classroom for effective instruction and productive student learning. In addition to exploring the forms of knowledge that ODP teachers need for effective teaching, the research on which this paper is based deals with understanding and extending the frameworks that have been used in unpacking teacher knowledge in the past. This is because this research is located primarily in technology, and so a framework for understanding and unpacking knowledge of teachers teaching with the use of technology needs to have a technology dimension. It appears that in the initial framework conceptualization, Lee Shulman did not explicitly discuss technology and its relationship to pedagogy and content. Does this mean that this link was considered insignificant? Recent research in the field of education is now attempting to bring specific attention to the technology dimension of teaching and learning by examining how technology interacts with: (1) pedagogy, as Technological Pedagogical Knowledge (TPK), (2) content, as Technological Content Knowledge (TCK), and (3) jointly as Technological Pedagogical Content Knowledge (TPCK) (Mishra & Koehler, 2005). The research being proposed draws from the TPCK framework, and reviews the relevance of this TPCK framework for understanding and unpacking ODP teachers’ knowledge within the context of ICT-based classrooms.

Building on Shulman’s idea of PCK, Mishra and Koehler (2006) added technology knowledge to PCK, and described TPCK as the interweaving of technology, pedagogy, and content. Figure 1 shows the seven knowledge component of TPCK.
Figure 1: The TPCK framework (Koehler & Mishra, 2008)

The theoretical TPCK model advocated by (Koehler and Mishra, 2005; Mishra and Koehler, 2006; Koehler & Mishra, 2008; Schmidt, 2009) might serve as an appropriate model to direct technology training. The TPCK model depicts how teachers understanding of technologies and pedagogical content knowledge interact with one another to produce effective teaching with technology (Koehler & Mishra, 2008). However, the standard TPCK model does not adequately address all the various types of technology knowledge explicitly. The TPCK framework emphasis knowledge as it applies to technology enhanced classroom, but did not adequately address the application of technological knowledge and skills in ICT-based classrooms such as ODP.

Knowledge as applied to science, technology and engineering covers declarative(content or know that), functional(know how) and procedural(skill or knowing) knowledge (Nissen, 2006; Ferris, 2009). There is a clear distinction between these type of knowledge in the context of ICT-based classroom instruction such as ODP, which for instance might have a different meaning to a teacher of geography and social studies.

The general TPCK conceptual framework might need to be interpreted differently for use in the context of a very specific discipline in technology, for instance in ODP. By studying the nature of teachers TPCK in ODP, we intend to ascertain whether the adaptability of the theoretical model could be extended for ODP instruction in an ICT-based classroom. This effort will hopefully enhance office management technologist and secretarial training at FET colleges and will lead to the development of an effective, holistic, theoretically grounded approach. It is also anticipated that improvement in the quality and effectiveness of ODP teaching and learning in ICT-based classroom will benefit learners and potentially extend to other vocational and technology courses.
The study
The study aim to unveil the dynamic relationships between different types of knowledge, Especially as it applies to the effective delivery of ODP instruction in ICT-based classroom.
The study also hopes to make significant contributions to specific and practical refinements of the TPCK framework as applied to the actual ODP in ICT-based teaching and learning environment.

Methods
An ICT-based Survey Data Template questionnaire of beginning and veteran ODP teachers Procedural, Functional, Pedagogical and Content knowledge (PrFPACK) in ICT-based classroom, building on (Schimidt, D. Baran, E. Thompson, A. Koehler, M.J. Mishra, P. & Shin, T. 2009) and (Foster, P.A. Vaille, M. Dawson & Doug Reid, 2005) which includes 65 items organized into thirteen subcategories of knowledge, each subcategory relates to a specific theoretical construct (PK – pedagogical knowledge, CK – content knowledge, FK – Functional knowledge, PrK – procedural knowledge, PCK – pedagogical content knowledge, PFK – pedagogical functional knowledge, PrCK – procedural content knowledge, PrFK – procedural functional knowledge, PFCK – pedagogical functional content knowledge, PrCFK – procedural content functional knowledge, PrFPK – procedural functional pedagogical knowledge, PCPrK – pedagogical content procedural knowledge, PrFPCK – procedural functional pedagogical content knowledge. The questionnaire addressed knowledge and skills to do with Spreadsheets, Audio typing, Advanced database, Computer file management, advanced presentations, the World Wide Web and Interactive teaching whiteboard. In line with National Certificates Vocational NC(V) new curriculum standard and ICT White paper policy (DoE, 2007). Each point has responses on a five-point likert-type scale (1= highly incompetent, 5=highly competent). The initial draft of this template will go through a series of iterative revisions based on the measurement principles of the two existing instruments mentioned earlier and will be reviewed by expert review committee in ICT faculty in the University.
Pilot Testing
The extended TPACK Instrument, PrFPACK will be tested with a group of 15 ODP beginning and veteran teachers in FET colleges in Gauteng province of South Africa. The teaching experience of these teachers ranged from 1-25 years and above in ICT-based classroom. By involving both beginning and veteran teachers in the study, the aim will be to determine differences and similarities in their knowledge of ODP, and how the knowledge differences and similarities are linked to the teachers’ use or non-use and understanding of technology in the classroom. Four ODP teachers will be selected from the quantitative data result to be observed through classroom observation, video recordings, interviews, reflective journals and document analysis.

Data Analysis
Rasch analysis will be conducted using Winsteps computer software (Linacre, 2009). Rasch analysis provides insight into the extent to which teachers possess the knowledge and skill that is being investigated. The qualitative portion of this exploratory study will be used to explore relationships found in the quantitative data.
<table>
<thead>
<tr>
<th>Knowledge construct</th>
<th>Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Pedagogical</td>
<td>A response that shows methods and teaching strategies</td>
</tr>
<tr>
<td>2. Content</td>
<td>A response that shows understanding</td>
</tr>
<tr>
<td>3. Functional</td>
<td>A response that shows know how</td>
</tr>
<tr>
<td>4. Procedural</td>
<td>A response that shows effectiveness</td>
</tr>
<tr>
<td>5. Pedagogical content</td>
<td>A response that shows understanding of different methods and strategies of teaching</td>
</tr>
<tr>
<td>6. Pedagogical functional</td>
<td>A response to know how to use different methods</td>
</tr>
<tr>
<td>7. Procedural Content</td>
<td>A response that shows effective understanding and performance</td>
</tr>
<tr>
<td>8. Procedural functional content</td>
<td>A response that shows understanding of know how effectively</td>
</tr>
<tr>
<td>9. Pedagogical functional content</td>
<td>A response that shows understanding of how to use different methods</td>
</tr>
<tr>
<td>10. Procedural functional</td>
<td>A response that shows effective know how</td>
</tr>
<tr>
<td>11. Pedagogical procedural</td>
<td>A response that shows knowing and use different strategies effectively</td>
</tr>
<tr>
<td>12. Pedagogical functional</td>
<td>Know how to use different strategies effectively</td>
</tr>
<tr>
<td>13. Procedural functional</td>
<td>A response that shows effective understanding of Application of different strategies</td>
</tr>
</tbody>
</table>
It is anticipated that improvements in the quality and effectiveness of ODP teaching and learning in ICT-based environment will benefit trainee and potentially extent the application to other vocational and technology education courses.

References


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The application of concepts in electricity through Design activities during a Technology Education Class

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Abstract
The purpose of this paper was to explore how pre-service students' experiences in a Technology class during the design and construction of artefacts (in this case model houses) can be used to inform the teaching of concepts in electricity. The research was designed from a constructivist learning perspective. Data was collected from classroom observations made from a convenience sample of one hundred and fifty pre-service second year students. Also, structured and semi-structured interviews will be carried out. The students were from a South African University in the province of Kwa-Zulu Natal. The pre-service students' electrical drawings and models showed knowledge of sources of electricity, wiring, resistance, connection of bulbs, switching and abilities to move between diagrammatic representations and objects. This knowledge and the pre-service students' engagement with construction activities provided a sound basis for more formal discussions of concepts in electricity.

Introduction
Brijlall et al (2006) investigated the development of geometry based on learner experiences. They found that the knowledge and the learners' engagement with construction activities provided a sound basis for more formal discussions of geometry. That study involved grade 9 school learners. This study also interrogates the construction of model houses. However, this study differs in two ways: 1) it involves students at a university, 2) students understanding of concepts in electricity when designing model houses.
Learning without participation is also in contradiction with the recommendations of constructivists such as Von Glasersfeld (1984), Cobb (1994), Confrey (1990) and Steffe (1992). Von Glasersfeld (1992) argued that reflective ability is a major source of knowledge in all levels of mathematics. This implies it is important for pre-service students to talk about their thoughts to each other and the lecturer. These constructivists focus on the quality of individual interpretive activity, including the development of ways of knowing and interactive performance in the Technology classroom.

Keeping in mind the constructivist viewpoint that learning is student-centred and not a passive process, the construction of model houses by pre-students offered an active learning experience. The activity is part of Technology Education 210, a module offered to second-year pre-service students in the Bachelor of Education Degree curriculum.

Technology, as a compulsory learning area alongside Science and other subjects in South Africa, requires purposive activity in the design and representation of artefacts, and can provide a valuable context for thinking about and using concepts in electricity. In particular, the way the pre-service students represent an artefact and the electrical circuitry reflects the ways that he or she interprets concepts in electricity. This study planned to increase and encourage the integration of Science with Technology and other learning areas as suggested by the Revised National Curriculum Statements (DOE, 2005). It sought to identify the uses pre-service students make of concepts in electricity when constructing and designing model houses in a Technology classroom, and hence to suggest changes to the ways we understand and teach concepts in electricity in Technology classes.

Through designing, pre-service students engage in the various concepts in electricity like obtaining different voltages, obtaining various brightness of bulbs, measuring, testing and linking electrical and graphic drawings to the artefact. In particular, students have to move back and forth between the concepts in electricity and their representation in drawings.

A great number of pre-service students perform poorly in concepts in electricity (Gayadeen, 2010). Alternative approaches are required. Consistent with constructivist learning theories, Mogari (2000) suggested that geometry content can be more meaningful if it is taught in practical and familiar contexts, related to the cultures and interests of the pre-service students. He also proposed that mathematics should not be taught in isolation from other subjects but should demonstrate its value across the curriculum. This study extends the suggestions made by Mogari into concepts in Electricity during the design of model houses in a Technology Education classroom. Anderson (1980) argued that teaching mathematics in purely abstract, symbolic ways, detached from cultural aspects, is not only ineffectual, but harmful to the student, society and mathematics. Gerdes (1997) argued that geometrical forms and patterns inherent in traditional African objects like baskets, houses, mats and fish-traps constitute knowledge about the properties and relations of different geometric shapes and ideas and should be part of mathematics learning. This study explores the notion in Technology Education.
These positions are consistent with policy in South Africa. Amongst the critical and developmental outcomes of the National Curriculum Statements (DOE, 2003), for example, pre-service students should be able to reflect on and explore a variety of strategies in problem-solving, communicate in a variety of ways, and be culturally and aesthetically sensitive across a range of social contexts.

Research methodology
The research question was: How can learner experiences via design activities during Technology lessons foster the development of basic concepts in electricity and ideas? Our particular interest was to work closely with pre-service students during Technology classes, to document the ways they moved between their informal knowledge of concepts in electricity and the design and construction processes, and the ways their knowledge could be used as a basis for more formal learning of concepts in electricity. Thus the research was essentially interpretive, and based in constructivist views of learning and the policy position expressed in the Revised National Curriculum Statements (DOE 2005).

This research is based in the qualitative paradigm. Qualitative research attempts to collect data that is rich and descriptive in order to understand the phenomenon that is being studied or observed. It thus focused on how groups or individuals view the world and how they derived meaning from their personal experiences (Niewenhuis, 2007, p.50).

Qualitative research is typically concerned with exploring the ‘what’ and ‘how’ questions of research. It is concerned with studying people in their natural environment and focusing on their perceptions and interpretations. This exemplifies this research as it studied the pre-service students in their natural environment.

In qualitative research “the emphasis is on the quality and depth of information…” (Niewenhuis, 2007, p.50). This therefore justifies the interpretivist paradigm where the individuals were interrogated and their interaction with the phenomenon that was being investigated was regarded as being paramount.

Artefact Specification
Two different tasks involving the design and construction of artefacts were developed for the purpose of this study. The tasks involved objects that the pre-service students were familiar with: either a single-storey or double storey house. Students had to research various ideas and designs of houses and utilise or design one idea. The students were asked to design the houses firstly on paper, using drawings showing the various views, materials used, electrical diagrams and then construct the model of the house.

The following specifications had to be adhered to with regard to the construction of the artefact:

Part: One
- Size not bigger than A3
• Your house should consist of three bedrooms and other rooms that exist in a house
• You need to decorate the house with appropriate furniture
• Your house can be double story (not compulsory)
• The roof must be able to be removable or hinge open
• You may use whatever materials available. Be original in using recycled materials
• Your design must be rigid

Portfolio:
Must include the following:
• Cover page (Student name, student number and title)
• Content page
• Investigation/design of four different house designs. Include the pictures/drawings and details of each house
• Design and specifications of your dream house
• Drawings of the various views of your house. Include a plan view of your house. Drawings must be drawn to scale and must be labelled.
• List actual materials you will be using to build your house. Give reasons why you chose specific materials
• List tools used
• Detailed plan of how you will build your house. List the various stages. (Pictures/photos can be included)

Part: Two
Electricity
Your house needs to be wired according to the following specifications:
• Each room must have a light operated with a switch
• There must be a mains switch to control all the electricity in the house
• Lights must be attached from the ceiling and switches must be on the wall
• Attention to detail and neatness of wiring must to taken into consideration
• You must provide a detailed wiring diagram of your house (find out how this is usually presented)

Part two of the project provided rich opportunities for thinking about concepts in electricity and its application in circuits. Pre-service students worked with electrical drawings, imagination, and the models they were making.

Background of Participants
The study was undertaken with a group of one hundred and fifty second year pre-service students at the University of Kwa-Zulu Natal, in the province of Kwa-Zulu Natal, South Africa. The students were split into four groups. The choice of participants was made because the researchers were known to the students and had rapport with and access to
the students. Structured and semi-structured interviews were conducted to establish what transpired in and out of the lecture room. During activities, data were collected through observations and questioning, captured on audiotape and later transcribed. Observations were made of every activity (e.g. construction, testing, soldering and wiring) and notes on every activity were kept.

**Projected Outcomes**

Of particular interest were the concepts in electricity that appeared in the finished artefact, whether the completed artefacts represented a true model of the object (a single-storey or double-storey house), and the thinking that pre-service students were doing. The interviews were directed at how each student started drawing a house, through to the finished product. Pre-service students' electrical diagrams and responses to questions about their diagrams provided information about their understanding of concepts of electricity and the ways they interpreted the diagrams and circuits. The electrical diagrams, drawings and models, audio and video recordings were reviewed together to assist in unpacking and verifying pre-service students' responses during the interviews.

**Pre-knowledge**

This project was undertaken with students having basic prior knowledge of constructing and wiring electrical circuits. Students were taught during theory lessons about resistance, current, voltage, insulators and conductors, switches and switching and series and parallel circuits. Further, these concepts were reinforced, were students had to draw various electrical circuits and wire them accordingly. They had to test for quantities such as resistance, voltage and current and observe there behaviour in series and parallel circuits.

**Results and Findings**

The assessment for this activity comprised of three stages: 1) portfolio, 2) artefact and 3) electrical circuit. The portfolio entailed the criteria: 1) investigation and design, 2) design & specification, 3) drawing, 4) materials, 5) utilised, 6) steps to construct artefact, as indicated in Table: 1

Table: 1 Mark Allocation for Portfolio

<table>
<thead>
<tr>
<th>RANGE</th>
<th>INVESTIGATION AND DESIGN</th>
<th>DESIGN &amp; SPECIFICATION</th>
<th>DRAWING</th>
<th>MATERIALS UTILISED</th>
<th>TOOLS UTILISED</th>
<th>STEPS TO CONSTRUCT ARTEFACT</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 49</td>
<td>58</td>
<td>82</td>
<td>90</td>
<td>5</td>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td>50 – 74</td>
<td>46</td>
<td>62</td>
<td>42</td>
<td>0</td>
<td>0</td>
<td>85</td>
</tr>
<tr>
<td>75 -100</td>
<td>46</td>
<td>6</td>
<td>18</td>
<td>145</td>
<td>142</td>
<td>25</td>
</tr>
</tbody>
</table>

230
Despite ninety seven percent of the students utilise appropriate material and ninety five percent utilising appropriate tools only four percent of the students provided excellence in design and specification. This seems to suggest having the appropriate resources does not necessarily imply a superior artefact design. The low percentage of the students who performed with distinction in the steps required to construct the artefact (seventeen percent in the distinction range) seems to suggest the correlation with the four percent who excelled in the design and specification. This further suggests that pre-service students who were methodical in their planning were highly successful in providing the expected artefact design and specification. An illustration of a well planned artefact construct appears in Figure: 1.

![Diagram of Andy's house plan](image)

Figure: 1 Andy’s house plan

The artefact entailed the criteria: 1) size, 2) furniture, 3) roof, 4) rigid, 5) neatness and workmanship, 6) additional feature, as indicated in Table: 2.

Table: 2 Mark Allocation for Artefact

<table>
<thead>
<tr>
<th>RANGE</th>
<th>SIZE</th>
<th>FURNITURE</th>
<th>ROOF</th>
<th>RIGID</th>
<th>NEATNESS &amp; WORKMANSHIP</th>
<th>ADDITIONAL FEATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 49</td>
<td>7</td>
<td>32</td>
<td>37</td>
<td>49</td>
<td>32</td>
<td>91</td>
</tr>
<tr>
<td>50 – 74</td>
<td>25</td>
<td>31</td>
<td>103</td>
<td>62</td>
<td>77</td>
<td>33</td>
</tr>
<tr>
<td>75 -100</td>
<td>118</td>
<td>87</td>
<td>10</td>
<td>39</td>
<td>41</td>
<td>26</td>
</tr>
</tbody>
</table>

It is noted that seventy nine percent of the students (in the distinction range) were able to comply with the expected artefact size. The majority of students were able to design the artefacts within the given norms. A trend noticed was that sixty one percent of candidates performed poorly in the category of “additional feature.” This seems to suggest that the pre-service students did not take the initiative to provide anything more of originality. In Andy’s artefact, as illustrated in Figure: 2, many additional features were considered in the design. Andy included gutters for water drainage, fascia boards, ceiling and he also
made visible the roof trusses.

Figure: 2 Andy’s completed artefact

The electrical circuit entailed the criteria: 1) main switch, 2) mounting of switches, 3) neatness, 4) soldering, 5) operation, as indicated in Table: 3.

Table: 3 Mark Allocation for Electrical Circuits

<table>
<thead>
<tr>
<th>RANGE</th>
<th>MAIN SWITCH</th>
<th>MOUNTING OF SWITCHES</th>
<th>NEATNESS</th>
<th>SOLDERING</th>
<th>OPERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 49</td>
<td>38</td>
<td>15</td>
<td>99</td>
<td>105</td>
<td>46</td>
</tr>
<tr>
<td>50 – 74</td>
<td>0</td>
<td>31</td>
<td>39</td>
<td>37</td>
<td>81</td>
</tr>
<tr>
<td>75 -100</td>
<td>112</td>
<td>104</td>
<td>12</td>
<td>8</td>
<td>23</td>
</tr>
</tbody>
</table>

Seventy five percent of the students were able to perfectly connect a main switch to the circuit. Seventy percent of the students (in the distinction range) effectively mounted the individual switches. A high percentage (sixty six percent) of the pre-service students submitted sloppy workmanship in wiring. Seventy percent of the pre-service students performed dismally in the category of soldering. Soldering required a refined skill which seems to lacking in these students. There is no correlation between the thirty percentage “operation” failure rate with the pre-knowledge. This is further highlighted by the fifteen percent of pre-service students who provided fully operational electrical circuits. An example of a fully operational circuit was submitted by Busi as indicated in Figure: 3.
The following concept in electricity used and revealed by the pre-service students in the drawing of artefact:

- Source of electrical circuits
  The pre-service students displayed knowledge in connecting cells in series. They realised that a series connection would yield a larger voltage. This was shown in their portfolio write-up.

- Wiring
  Most candidates made the correct choice in the type of material to be used as conductors. The purpose in their choice was explained when they discussed conductivity in electrical circuits.

- Resistance
  These pre-service students correctly related bulbs as resistors. They could calculate the net resistance of resistors in series and parallel.

- Bulbs
  In many cases where circuits were un-operational, the pre-service students did adhere to the operating specifications of the bulbs. In most cases they incorrectly connected bulbs in series, instead of parallel.
• **Switches**
Seventy five percent of the students correctly connected a main switch and seventy percent could correctly mount the individual switches in rooms.

• **Multimeter**
This artefact activity encouraged the pre-service students to make use of meters to measure the current strength, potential difference and resistance of the circuitry.

• **Circuit Diagram**
The pre-service students were able to submit the relevant circuit diagrams highlighting the use of symbols depicting the respective components. This is illustrated in Figure: 4 by Tom’s circuit diagram.

![Figure: Tom’s circuit diagram](image)

**Concluding remarks**
The study has shown that when concepts in electricity is set into the context of designing and constructing an artefact, such as a model house, pre-service students are able to demonstrate, articulate and build on their common-sense knowledge of concepts in electricity. Tasks can be designed that capitalise on these possibilities and at the same time promote a wide range of learning outcomes. This suggests a number of recommendations:
- Development and use of specific skills displayed by pre-service students in other learning areas can be enhanced by pre-service students’ knowledge and appreciation of concepts in electricity and their attitudes towards it. Technology, with its emphasis on the design, construction and evaluation of artefacts is a fruitful learning area. Our study has demonstrated possibilities for conceptual understanding in the design and construction of a model house, but extensions readily come to mind, such as application problems involving the cost of tiling floors or painting buildings.
• Representation of artefacts and objects in the form of designs and drawings from the pre-service students' perspectives contribute to their visualisations of shape and space, which are necessary for Technology Education. These visualisations can be interrogated to guide and deepen pre-service students' understanding.

• Pre-service students can describe and represent their experiences with concepts in electricity irrespective of the prescription of the syllabus for the grade concerned. Opportunities arise for pre-service students to grasp concepts at different levels and paces in keeping with their individual abilities.

• Pre-service students can use any language (or a number at once) to communicate ideas, concepts, generalisations and thought processes. Beyond the use mother tongue and English, they can use visual representations.

• Pre-service students can perform the activities based on objects, representations and ideas from their own experiences and cultures and discuss their presentations.

• Such activities afford opportunities to extract informal ideas of concepts in electricity from the pre-service students' real-world experiences. One requirement for this extraction is the framing of suitable questions by the teacher. For example: Why are the bulbs connected in parallel? A second requirement is that the class builds on the pre-service students' ideas, advancing their formal knowledge of concepts in electricity.

• Pre-service students should be regarded and enjoyed as intelligent and creative individuals whose questions are valued. Tasks that allow pre-service students to take initiatives, express their ideas, reflect on their thinking and build their understanding can readily be designed. Group work can be planned to facilitate such discussions.

• Teachers can introduce and present concepts in electricity in interesting and joyful ways. This study shows one instance of how that can be achieved, through linking concepts in electricity to the design and construction of artefacts.

Teaching that provides opportunities for pre-service students to struggle with problems of conceptualising and communicating their diverse and personal intuitive thought, and builds on this knowledge to construct notations, proofs, definitions and the appreciation of concepts in electricity as a whole takes time and planning. It also provides opportunities for learning beyond Technology Education content but linked to it. For example, pre-service students gathered information on how they could build a multi-storey house and materials available for the process. During the construction, they considered the size of the artefact, recorded measurements and predicted the different walls to be constructed before the others were done. They identified congruent faces of their buildings, compared similar sides and used scale drawings and various projections in their drawings. They developed knowledge and skills related to graphics, such as uses of colour, rendering techniques, two-dimensional and three-dimensional drawings, planning, sketching, drawing and calculating, and knowledge and skills in constructing their models. They managed resources and time, worked together and alone, communicated in a variety of ways, critically evaluated their work.

Acknowledgement
The first author would like to thank Professor V Wedekind for making available financial support (via the continuous sector of the University of KwaZulu-Natal) for the attendance of this conference.
References


The effect of Advanced Certificate in Education technology training on in-service teachers’ professional development regarding their knowledge and understanding of technology

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The aim of this paper is to assess the effect of the Advanced Certificate in Education (ACE) technology in-service training towards technology teachers’ professional development regarding their knowledge and understanding of technology. A questionnaire was administered to 304 Gauteng Province and Mpumalanga Province teachers that Department of Education (DoE) sponsored to attend a two-year MSTE (science, mathematics and technology education) ACE for their professional development. For purposes of this paper the focus was on technology education. The questionnaire was administered prior to and post the ACE technology training. A null hypothesis was stated: There is no statistically significant difference between the pre- and post-ACE technology training scores for teachers’ professional development regarding their knowledge and understanding of technology. In general, this null hypothesis could be rejected due to the findings showing that the ACE technology training added to the knowledge and understanding of teachers.

Key words: Advanced Certificate in Education, technology, professional development, in-service training.

Background of the study

The introduction of Outcomes Based Education (OBE) in the form of Curriculum 2005 (C2005) brought an educational reform in South Africa. C2005 was reviewed twice and became known as Revised National Curriculum Statement (RNCS), National Curriculum Statement (NCS), and now Curriculum and Assessment Policy Statement (CAPS). CAPS will be implemented in 2012 (DoE, 2005; 2010). Since the pedagogic practice of OBE differs from the previous practice (Ono & Ferreira, 2010) an intensive continuous professional teacher development is imperative to prepare them for the implementation the curriculum. However, the training of many teachers who were under-qualified and unqualified is still incomplete (Taylor & Vingevoeld, 1999; Jansen & Christie, 1999). Although the qualifications of many teachers in the country have improved, most reports indicate that the majority of teachers have not been sufficiently equipped for the educational needs of modern society (DoE, 2006) in terms of their content knowledge (subject matter) and pedagogic skills (Aluko, 2009). Most studies in teacher development reveal a serious unpreparedness of teachers’ pedagogic skills in addressing learners’ individual differences (Kent, 2004; Laine & Otto, 2000). Adequate time should be available for teacher studies and planning for effective curriculum implementation (Laine & Otto, 2000). Drawing from the American example, it was found that most school districts are usually provided too little time
for teachers’ professional development (Kent, 2004) so to arrive at best judgement about learners’ needs. Thus, this study is guided by teachers’ professional development perspective with special reference to in-service technology training. “Teacher development is the professional growth a teacher achieves as a result of gaining increased experience and examining his or her teaching systematically” (Gatthorn in Villegas-Reimers, 2003: 11). It follows that teachers are pivotal to the success of change (Brown, Sithole & Hofmeyr, 2000; Langer, 2000; DoE, 2006; Kent, 2004; Castellano & Datnow, 2000). Many studies have shown that teacher competence in pedagogic and content knowledge is crucial for learner achievement (Pikulski, 2000; Darling-Hammond, 2000; Rivers & Sanders, 1996; Kent, 2004; Borko, Elliott, McIver & Wolf, 2000). The current situation is that there are about 40% unqualified and/or under-qualified teachers (DoE, 2009). Many teachers still hold diplomas only (Welch, 2009). In terms of technology education, technology education was introduced as a relatively newcomer in the curriculum (Maluleka, Wilkinson & Gumbo, 2006). There were no trained technology teachers at its inception. They were qualified only in other subject fields that they taught. They were asked by DoE to volunteer to teach technology, starting on a lean pedagogical and content knowledge. As part of formal two-year qualification, DoE (2000) decided on the ACE to try to fast-track teacher training. This is in line with one of the principles of National Policy Framework for Teacher Education and Development in South Africa, which states that “a teacher should be a specialist in a particular learning area, subject or phase” (DoE, 2006: 5). In-service teachers were then sent for training during school holidays and on Saturdays. DoE basically outsourced the training to Higher Education Institutions. The authors were involved as facilitators from 2008 to 2009. The training targeted technology teachers for General Education Training band from Gauteng Province (Sebokeng, Johannesburg North, Soweto and Tswane West Districts) and Mpumalanga Province (Bushbuckridge District). The researchers were keen to know the effect that this training made in terms of developing the technology teachers to teach technology. Hence, they integrated their facilitation with a research project.

Research design

The research question that this study addresses is stated as: Is there any significant difference between the scores of pre- and post-in-service ACE training of technology teachers’ professional development regarding their knowledge and understanding of technology? It can thus be hypothesized: There is a statistically significant difference between the pre- and post-in-service ACE training of technology teachers’ professional development regarding their knowledge and understanding of technology. It can also be null-hypothesized: There is no statistically significant difference between the pre- and post-in-service ACE training of technology teachers’ professional development regarding their knowledge and understanding of technology. A questionnaire was administered at entry level (beginning of 2008) of the ACE technology training to determine the teachers’ technological knowledge and understanding. This very questionnaire was administered at the exit level (end of 2009) of the ACE technology training to determine the impact that the training made regarding teachers’ technological knowledge and understanding. Permission to conduct this research was sought and granted by the organizing officials and through DoE officials who visited the training sites. Teachers also showed cooperation and willingness to fill in the questionnaires after the purpose of the study had been clarified to them. The questionnaire was administered to teachers who were conveniently available on the days of data gathering. Coincidentally

238
the number of pre- and post-training responses was the same, i.e. 304. One-way frequency
distributions on respondents’ biographical attributes were calculated to provide background
knowledge on the sampled population and to determine which of the biographical attributes
could be included in further analyses to evaluate their affect on knowledge acquisition (over
and above the effect of the ACE course attendance). Two composite frequency tables on the
knowledge rating statements (14 statements) which respondents rated before and after
completion of the ACE training were created to provide a general overview of respondents’
perceived knowledge prior to and after the ACE training. A composite table was also
calculated on the differences between pre- and post- ACE training scores which respondents
supplied prior to and after this ACE training. The composite distribution table on differences
was visually examined to obtain first impression as to whether pre- and post-training ratings
could be expected to be the same (difference close to zero) or to differ (difference greater
than zero). Once this exploratory investigation had been conducted, the analysis strategy
turned to non-parametric test to statistically confirm (or reject) the exploratory indication.
The analysis strategy also included mean pre-, post- and difference scores for each one of the
fourteen knowledge statements. A non-parametric Wilcoxon Signed rank test was conducted
on all difference ratings over all the statements to evaluate the hypothesis that the mean
difference rating score would be zero (in other words no difference between pre- and post-
intervention scores). The test was also calculated on the difference scores for each
knowledge statement separately for each of the 14 knowledge statements. These tests were
conducted separately to obtain deeper insight into each aspect of knowledge that was probed.
Once the issue of the effect of the ACE training had been evaluated, the analysis strategy
investigated the effect that biographical attributes – such as previous technology tutoring
experience, previous technology training, etc. could possibly have on the expected increase
in technology knowledge (irrespective of the effect of the ACE training). Non-parametric
analysis of variance (Kruskal Wallis one way analysis of variance) was used to investigate
this issue further. Only the biographical information and pre- and post- differences tables
could be accommodated in this paper due to space.

Results
Table 1: One-way frequency distributions on respondents’ biographical attributes
The frequency distributions on the biographical attributes in Table 1 indicate that nearly half the respondents volunteered to do the ACE technology training, that approximately equal ratios of respondents had/did not have previous background training in technology education, that the experience was mostly gained from workshops that lasted in most cases more than a week, and that respondents in possession of the technology qualifications mostly possessed attendance certificates (50 out of 304). Approximately half the respondents had taught technology in the past and 73% of the total of 304 respondents indicated that they were currently teaching technology. It can thus be deduced that most respondents were at present presenting technology and that very few of them had previous formal training in technology education, but that a large majority had had practical exposure to technology tutoring.

Table 2: A composite table on the differences between pre- and post-in-service ACE training rating scores supplied by respondents prior to and after the ACE training
Deductions from Table 2 can be made bearing in mind the composite tables that were part of the analysis regarding the pre- and post-training. In terms of this, if the rating scale of no experience to extensive experience is interpreted to imply that when ‘no experience’ is indicated when respondents feel a ‘a substantial lack of knowledge’ to ‘extensive experience’ to indicate substantial knowledge or confidence, then the deduction can be made, that respondents in general lacked the academic/structural knowledge to teach technology. The analysis for pre-ACE training revealed that the majority of responses fell in the “no experience” to “moderate experience” categories. This could be pretty attributed to the fact that unqualified teachers in technology education were asked to volunteer to teach technology when it was implemented in 1998. On the other hand, if the rating scale of no experience to extensive experience is interpreted to imply that when ‘no experience’ is indicated when respondents feel a ‘a substantial lack of knowledge’ to ‘extensive experience’ to indicate substantial knowledge or confidence, then the deduction can be made, that respondents in general felt more relaxed regarding their academic/structural knowledge of technology once they had undergone the ACE training. The analysis for post-ACE training revealed that the majority of responses now fell in the “moderate” to the “more than average” experience categories. This result would imply that respondents seemingly felt more confident with regards to their knowledge and understanding once the ACE training had been completed. The distribution of differences between post- and pre- experience scores in Table 2 seem to agree with this finding. If kept in mind (from Table 2)
that the knowledge difference rating scores were calculated by subtracting the pre-ACE training score from the post-ACE training score for each respondent, the total frequency distribution row (last row of Table 2) seems to agree with the findings derived from the composite tables – the majority of frequencies (33% + 30% + 9%) fall within the 0 to 2 difference range – a positive difference – this, an increase – which indicates that respondents’ confidence in their knowledge re: technology knowledge and understanding seemed to improve from before to after the ACE technology training.

A highly significant Chi-square test statistic could be associated with each of the Wilcoxon signed rank tests that were performed on the difference scores. This implies that, firstly in general, the null hypothesis of no difference between the pre- and post-ACE technology teacher training scores could be rejected in favour of the hypothesis of statistically highly significant differences between the same. In general, respondents felt statistically significantly more at ease re: their technology knowledge and understanding once they had completed their technology specialized ACE training. The same deduction can be derived for each of the aspects of knowledge probed in the questionnaire. The non-parametric analyses of variance on the difference scores indicated that the following attributes affected the change in teachers’ confidence in technological knowledge:

• where respondents received their training: if training had been received at a training college respondents experienced significantly less change in their responses about technological knowledge than when they had attended training/workshops, or other institutions;
• the province in which they resided: teachers from Mpumalanga Province experienced a significantly greater change in technological knowledge than those from Gauteng Province;
• technology education qualification: a statistically significantly greater change in knowledge responses was experienced by respondents who had attendance certificates in technology to those with an Honours or second degree qualification;
• institution: the respondents who obtained their qualifications from a private institution experienced significantly less change in technological knowledge than those who had attained their qualification ‘in the job’ – institute; and
• Previously teaching technology: the respondents who had not previously taught technology experienced a significantly greater change in perceived knowledge than those who had taught technology previously.

Discussion of findings

The study in this paper aimed to assess the effect of the Advanced Certificate in Education (ACE) technology in-service training towards technology teachers’ professional development regarding their knowledge and understanding of technology. The findings reveal that teachers benefited from the training – the majority of frequencies (33% + 30% + 9%) fall within the 0 to 2 difference range (composite Table 2). The majority of responses now fell in the “moderate” to the “more than average” experience categories, an indication that teachers benefited from the training in terms of their knowledge and understanding of technology. The teachers’ biographical attributes presented some noteworthy perspectives on the findings. Teachers who lacked any training background in technology benefited more from the ACE technology

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training. This could be related to their heightened determination to learn more from the training to fill their uninformed gap. This is responding to DoE (2006), Taylor and Vingevold (1999), Jansen and Christie (1999) and Aluko (2009), who claimed that the training of many teachers who were under-qualified and unqualified is still incomplete. Teachers who previously received their training from college benefited less from the training compared to teachers who attended workshops previously. The longer institutionally based training for the college teachers could be the reason for benefiting less as they could have gained some degree of knowledge and understanding of technology from their college training. An interesting finding that was not expected is that the Mpumalanga Province teachers experienced a significantly greater change in technological knowledge post-ACE technology training compared to those from their Gauteng Province counterparts. That could also be accounted for by their higher level of commitment that they showed in learning technology during this training given “the rural environment” where they work, assumed to be “technologically poor”. Furthermore, teachers who had attendance certificates in technology experienced greater knowledge compared to those with an Honours or second degree qualification, the same those who received on-the-job training compared to those who received their training from private institutions. Those with an Honours degree could already be more knowledgeable, and those with on-the-job training could be more advantaged to implement what they learnt immediately. Teachers who had not previously taught technology benefited from the ACE technology training more than those who had taught technology previously. Those who had taught technology previously could have much exposure to technology already, that they could identify well with what the ACE technology training covered. The benefit that these categories of teachers derived from the training based on their biographical attributes is in keeping with DoE’ (2006) intention with the ACE programme – for teachers to become specialists in their subject areas.

Limitations
Methodologically, the potential limitation lies in the single and common data gathering instrument (questionnaire) for all the 14 knowledge areas. A mixed method approach which integrated interviews with teachers could have yielded in-depth insight regarding the extent to which they benefited from the training. Another potential limitation is that these findings are about the two-year ACE technology training. They may not necessarily be generalised to other types of training. The findings were also about the training for the Gauteng Province and Mpumalanga Province ACE technology teacher training. They may thus not be easily generalised to other provinces.

Recommendations
Technology teacher training should be preceded by the profiling of teachers and needs analysis so that strategic decisions can be taken to vary the depth and nature of their training in terms of profile and needs categories. Teachers without any training background in technology should preferably be given special attention in terms of training. For those with some training background, only specific gaps or areas of need should receive attention in their training.
Further studies should consider mixed methods in their assessment of the impact of training on the teachers. A study of this nature can be extended to other provinces in future. Other types of technology teacher training suggest studies that should assess their impact on the training itself.

Conclusion
This paper reported the outcome of the study that enquired into the effect of the ACE training of technology teachers’ professional development regarding their knowledge and understanding of technology. In terms of the research question and the hypothesis that was stated, the main finding of the study is that the ACE training in technology education enhanced teachers’ knowledge and understanding of technology. This is an important finding considering the fact that technology education is relatively a new learning area/subject and that for that matter there is dire need for training teachers to offer the same to learners. Furthermore, the training of teachers in the field should be seen to make a difference in their knowledge of technology and the methodologies of presenting it to the learners. It is hoped that teachers who underwent this training are now serving their learners in schools by implementing what they have acquired.

References
A critical reflection on curriculum review of technology education in South Africa

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Abstract
The purpose of this paper is to critically reflect on curriculum review of technology education in South Africa. Guided by the theoretical framework, the researcher gathered views of lecturers, Department of Education’s officials and officials of other agencies involved in the development of technology education, all these in Gauteng Province. This was an e-mail data gathering. The findings shed light on the merits and demerits of technology education curriculum review in terms of intermediate-senior phase transition, technology teacher training, higher education institutions’ role, physical resource provisioning and sci-tech tug of war.

Key words: technology, technology education, technology learning area, curriculum.

The problem in context
The changes leading to democratic South Africa led to the introduction of a new
curriculum post-1994. The then Curriculum 2005 (C2005) replaced the pre-1994 apartheid inclined curriculum. C2005’s aim was to cleanse the curriculum of its racist and sexist character and infuse democratic values, social justice and fundamental human rights (African National Congress, 1994a; 1994b; Department of Education, 1995; 1996; 1997; 2009; Chisholm, 2003). C2005 was implemented in 1998. For the first time technology education was included in C2005, in step with the global trends (Stevens, 2005). It was integrated with Natural Science at intermediate phase (grades 4-6). It was anticipated that technology education would flourishingly thrive as part of the national strategy to skill and impart technological knowledge to the country’s learners. However, the growing of Technology Learning Area (TLA) has been confused by the curriculum reviews. Thus, this paper reports on the study conducted about the impact of curriculum review on the implementation of TLA.

Since the inception of C2005 the curriculum has undergone a few review metamorphoses. The first review happened in 2000 (Chisholm, 2003). This review recommended that the scrapping of TLA in order to lessen curriculum overload. This recommendation was declined by the authorities reported to. It was rather decided that the intermediate phase TLA be separated from natural science. C2005 also experienced a name change to the Revised National Curriculum Statement (RNCS). The second curriculum review in 2009 made TLA the casualty of curriculum overload once more. As a result TLA was remerged with natural science at intermediate phase. The review triggered ambivalence about the implementation of TLA. (Hacker, 1999) states in this regard, that a number of impediments have thwarted efforts to institutionalize technology education in the nation’s schools and have mitigated against its establishment as a core discipline. The problem that this study addresses is: What opportunities and challenges does the latest technology education curriculum review present in terms of:

- phase transition from intermediate phase to senior phase?
- human capital with specific reference to technology teachers?
- higher education institutions as teacher training institutions?
- physical resource provisioning?
- the science-technology (scie-tech) tug of war?

Few studies conducted on the problem include those of Stevens (2006) and Kahn, Mphahlele and Volmink (2003). The studies respectively relate the constraints faced by technology education from the first curriculum review in terms of teacher training and introduction of technology education for politically motivated reasons. The contribution of this study is to locate the critical reflection on curriculum review on the global curriculum trends. The author opinionates that local changes that affect technology education can better be fathomed in the context of global curriculum reviews and models of curriculum approaches for technology education (Vries, 1992; Eggleston, 1993; Brown, 2008). The study offers a balanced critique instead of a predominantly negative view that seems to characterize the foregoing studies. This paper is thus intended to add to the knowledge area about how curriculum reviews affect the implementation of technology education. The paper also attempts to create awareness on a balanced critic about curriculum review. Relevant stakeholders in education, e.g. technology lecturers, technology teachers, independent service providers, technology education officials and
parents, should be aware of the impact of curriculum review so that strategic decisions can be taken to strengthen the positive aspects of the review, whilst curbing or resolving the negative ones. Thus, the scope of the paper covers the:

- the problem in context as covered above;
- theoretical framework:
  - brief background about developments of technology education;
  - models of approaches to technology education curriculum;
- impact of curriculum reviews on the implementation of TLA;
- empirical investigation into the research problem;
- presentation of findings and recommendations.

Theoretical framework
Technology education has no tradition or history in schools (Williams, 1996), only discernable in historical vocational programs from the traditional craft subjects (Glover, 1996; Kimbell, 1997; Page, 1996; Sherwood, 1996; Raizen, Sellwood, Todd & Vickers, 1995; Siraj-Blatchford, 1996; Williams, 1996). Change in industrial training placed greater value on factors like creativity, initiative, entrepreneurship and critical thinking and self-governed work teams (Williams, 1996). This resulted in workplaces characterized by participatory management styles, shared goals, multi-skilled workers and flat management structures to enable the managed and/or led the space to showcase their potential to develop. These requirements necessitated the school curriculum that is motivated by competencies that workers should possess (Williams, 1996). The relevance of educational programs was brought into question and action taken subsequently.

In the United States, the Department of Labour’s Commission on Achieving Necessary Skills (SCANS) developed ‘workplace know-how’ based on workplace competencies and foundation skills (Williams, 1996; Zuga, 1997) to create balance between theory and practice. In 1989, the United Kingdom Secretary of State for Education incorporated six core skills in the programs of all 16-19 year olds 1990 through the National Curriculum Council, i.e. communication, problem-solving, personal skills, numeracy, information technology, and modern language competence. In New Zealand, competencies (essential skills) were developed as part of the National Curriculum, namely communication, numeracy, information, problem-solving, self-management and competitive, social and cooperative, physical, and work and study skills. In Australia, the Mayeral Committee determined key competencies for young people for effective participation in the emerging patterns of work and work organization. These include communicating ideas and information, planning and organising activities, working with others in teams, using mathematical ideas and techniques, solving problems, using technology. In South Africa the above Australian competencies resonate with critical cross-field outcomes.

The Minister of Education in Australia declared: “The main sources of productivity growth are technological change, increases in capital intensity, improvements in labour efficiency and economies of scale. Education and training will play a vital role in productivity performance, directly conditioning the quality, depth and flexibility of our labour force skills” (Treatagust and Mather, 1990: 51).
Demands for curriculum change in Australia brought a shift in the teaching enterprise from the “traditional” teacher dominance to teacher-learner partnership which was ultimately captured in the new curriculum in South Africa to differentiate between the old and new teaching approach, which espoused the principles of facilitation of learning and learner-centred learning, amongst others. These global developments triggered a need to introduce technology education as a school subject to prepare learners for the new industrial demands. As a result different models of curriculum approach were considered for states and schools to choose from. These approaches are worth noting in this paper particularly because they play a role in curriculum reviews. These models are presented according to Black (1996) and Raizen et al. (1995) subsequently:

- **Craft approach:** characterized by knowledge and skills about materials; cultural and personal value; traditional design; learning activities that involve making things based on prescribed designs; classrooms that are equipped with machines and tools from woodworking, metal working, electrical, catering and textile trades.
- **Occupational/vocational approach:** characterized by hands-on transformation of materials into products; current industrial practice skills; classrooms that are equipped with machinery from industry.
- **High-tech approach:** characterized by modern technological approach to industry; desire to shape the skill base of future workforce.
- **Applied science approach:** characterized by scientific approach; use of science to explore new applications of technology; study of science and technology in close association with each other.
- **Technology concepts approach:** characterized by learning processes that cause technological developments; theoretical understanding rather than practical action; systems concept.
- **Design approach:** characterized by practical capability approach; active learner involvement in tackling realistic problems; design-make-evaluate activities.
- **Science-technology-society (STS) approach:** characterized by curricula organised around societal issues; connections between classrooms and outside world; study of technological innovation as driving force for social change; problem-solving.
- **Integrated subject approach:** characterized by integration of several subjects into a framework that provides understanding of technology and its interrelatedness with other disciplines, e.g. science, mathematics and technology.

The background presented this far casts light on the motive behind the technology education curriculum review coupled with context-specific reasons like addressing issues of curriculum overload in the case of South Africa. Indeed, the decision to reduce curriculum load at intermediate phase was to alleviate too much load for learners, short of there could be a gap between this phase and senior phase in terms of the knowledge depth to be covered. Regarding teacher training, a good number of technology teachers have received training this far. For example, Potgieter (2004) accounts for some 137 teachers who participated in workshops, and some 950 teachers who did Advanced Certificate in Education with Unisa. The author also participated in training 250 Senior Phase teachers in Gauteng and Mpumalanga in 2008 and 2009. However, it is not clear as to who will now be expected to teach technology – will it be science teachers, technology teachers, or a team of science and technology teachers? Challenges like those experienced by UK
(Stables, 1997) seem inevitable. On the other hand, technology teacher training has not been easy. Teachers were asked to volunteer to learn and teach technology for the first time. Sithole’s (2009) relates teachers’ lack of comfort with the training (also compare with Carl, 2005; Laukgsch, Aldridge and Fraser, 2007). According to Reitsma and Mentz (2009), short workshops by DoE do not offer teachers the opportunity to study and reflect on the new information. It can be noted from the findings by these authors: “only few of the subject advisors themselves, who acted as trainers, had training in technology education” (p. 20). This compounds the training problems. Higher education institutions (HEI’s) are earmarked to help train both pre- and in-service teachers. Due to the shortness of the training sessions, the quality of the training might be compromised to some extent. DoE seems restricted to a larger degree by labour laws to extent the in-service training of teachers and scheduling it during their holidays or weekends. Technology education presents an opportunity to a thinking teacher to resource his/her teaching by tapping into the available resources in the immediate environment. On the other hand, the new integrated subject can help heighten the need for resource provisioning. Sithole’s (2009) findings include amongst others, lack of teaching resources and improper training. This has also been identified as a constraint elsewhere (Olaniyan & Ojo, 2008). To integrate certain aspects of technology education into natural science is not an unthinkable possibility in line with the subject integration approach above particularly when one considers the interface that exists in maths, science and technology (Sanders, 1999; Kahn et al, 2003). However, this does not suggest a simplistic approach to just lump science and technology together (Millar & Osborne, 2000) as though the two were one and the same thing. The new name, “Natural Science and Technology” may downplay the marketability of technology education. Existing differences between the two should provide space for their individual status. Thus, Sanders (1999: 36) cautions: “Because of these fundamental differences, the study of technology must be much more than simply another unit of study added to the science curriculum. To be meaningful and effective, the study of the technological world requires an activity-based curriculum that includes the design, development, and evaluation of solutions to technological problems”.

Research method

This is a qualitative study. Data was gathered electronically. An e-mail interview was conducted (Salmons, 2007) to answer the research questions stated above. An open-ended questionnaire was e-mailed to the participants to gather their views about the impact of technology education curriculum review. A random sampling technique was conducted to select three university lecturers from three different universities around, three education officials and three consultants from private agencies, all these in Gauteng Province. The questionnaire was distributed via e-mail to all selected participants. The purpose of the investigation and ethical protocol – participants’ confidentiality, identity, permission and their right not to participate, etc. All three lecturers, one educational official and one private consultant filled and returned the questionnaire. The analysis followed a thematic approach according to the items in the questionnaire. The views were balanced to a very large extent between positive and negative regarding the impact of curriculum reviews on the implementation of technology education. The findings are presented subsequently.
Findings
Intermediate phase transition to senior phase
The views acknowledged the review efforts to reduce curriculum overload for teachers and learners. One lecturer said that if teachers are equipped in both learning areas (natural science and technology education), “they can develop a project that covers both as well as stress their relationship, e.g. a cardboard truck with electric circuits for lights”. Another lecturer said that the specific requirements in the now Curriculum and Assessment Policy Statement (CAPS) will lay the foundation in Intermediate Phase which includes certain aspects of technology and links to natural science. According to him the emphasis on the design process should have a positive effect about adapting it after the transition to senior phase. The third lecturer said that some teachers are familiar with the old topic based curriculum.

He however stated: “Learners are deprived of acquiring skills and knowledge in technology education at an early stage. The private agency consultant and education official both expressed the lack of synergy between the two phases. The private agency consultant in particular stated that the CAPS draft document does not include the design process at intermediate phase, providing no foundation for the same at senior phase. Another lecturer shared his views: “Technology might be underplayed and not offered the time and tuition it deserves; this might compromise its themes per se”. According to him, it would appear that the initiative to address the technological skills shortage and invest in the future of the South African citizens is being compromised. The third lecturer cautioned that the unfamiliar nature of the aspects of structures and systems and control in intermediate phase can create a tendency not to teach them thoroughly which will then impact negatively after the transition to senior phase.

Technology teacher training
According to the private agency consultant, the envisaged training/retraining of teachers will help natural science teachers by consolidating their understanding with that of technology. To one lecturer, there will not be any big change “since content knowledge is still in a form of topics, as in CAPS”. According to another lecturer, pedagogically, teachers know the logistics of lesson planning from their former training, particularly as the new approach in CAPS reverts back to the old. He further stated: “Minimal time can be required to develop teachers on the theme prescribed by the syllabus”. On the other hand, this lecturer’s views expressed his dismay about what he referred to as “chameleon speed” technology teacher training and teachers’ shallow technological knowledge. He also stated that some teachers might be redundant and redeployed as a result. To another lecturer, teachers who were still grappling with understanding the OBE curriculum are now supposed to change and learn new things. For the third lecturer, technology teacher training could become very diluted and one-sided because many providers will only concentrate on the basics as specified in the CAPS documents. According to the views of the private agency consultant, “former technology teachers will need training on former NS topics”, and “teachers’ morale will be dented by the ever-changing mode/curriculum and new teacher training”. To the education official, it is not clear yet what form of teacher training will result from this review.
The role played by higher education institutions (HEIs) in training technology teachers
The review presents certain opportunities to the HEIs according to the participants’ views:
Private agency consultant: “New developments of materials in line with the new natural science and technology subject”.
Lecturer: “If only DoE can issue some more tender programmes to all HEIs and then establish some forums to clarify expectations, terms of reference, as well as the process outcomes is only then that the training can yield some positive results. Content-based textbooks around technology should be easy to develop”.
Lecturer: “In some cases teachers will again require HEIs to train them in CAPS”.
Education official: “We really need the help of universities are much needed to provide training. DoE should partner with them and industry.

Lecturers expressed their views about the burden of programme reviews, e.g. one lecturer stated: “HEIs have to redesign their course from NCS to CAPS. They must develop INSET programmes to equip teachers. All their module content should be revisited and adjusted, aligned and modified to meet the transition demand. Course credits should be reworked and qualifications should be SAQA approved”. Another lecturer stated: “New special training will be called for placing additional pressure on the facilities and capabilities of HEIs”. According to the education official, universities should seriously consider the training model that caters for ongoing on site support for teachers that they trained”.

Physical resource provisioning
According to the private agency consultant, the demand for new resources might grow bigger, much to the agency’s advantage as a service provider to resource schools. He stated that new kits for the natural science and technology subject will need to be compiled. The education official expressed the idea that private agencies can come in handy to help provide resources teaching and learning. In terms of the views of one lecturer, it will now be possible for DoE to provide resources that will assure that technology education will receive the attention that is intended according to CAPS.

However, according to two lecturers, resource provisioning can be minimized at intermediate phase due to the limited content to be covered. One lecturer went on to say: “The education ministry should be prepared to spend and support schools with equipment needed. Will they do it since they have failed in the past decade?” This view concurs with that of another lecturer who claimed that there are still no adequate resources. To the education official this was a big concern.

The science-technology tug of war
According to one lecturer, for the unbiased teachers the situation presents an opportunity to end the sci-tech tug of war. The views of another lecturer expressed concern that teachers will now teach more of science than technology. For the third lecturer, learners will learn to appreciate the relationship between science and technology. According to him, technology teachers should be appointed to the head of department position to neutralize the dominance of science teachers. According to the private agency consultant, technology is different from science. He expressed the idea that South Africa is not
following international trends in how technology is delivered. The education official was worried that the integration of the natural science and technology education might play down the status of technology education.

Conclusion
The review of the technology education curriculum in South Africa has caused ambivalence in those that are directly or indirectly involved with technology education, e.g. lecturers. This paper has attempted to investigate this issue through literature review and empirical enquiry. A balanced approach into the enquiry was considered. The findings of the study were presented according to this balanced approach.

Laugksch, R.C.; Aldridge, J.M. & Fraser, B.J. (2007). Outcomes-based education in
South Africa: Using an instrument to assess school-level environments during the implementation. Paper presented at the 2007 conference at the Australian Research Association in Education at Fremantle.
Factors contributing to poor performance of FET college students in Engineering Graphics and Design

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Abstract

All students who choose Mechanical Engineering must also study Engineering Drawing as one of their major subjects, as it is the main prerequisite for future mechanical engineers. The purpose of this was to report on the factors contributing to poor performance of students in Engineering Drawing at Ekurhuleni West FET technical college in Gauteng Province, South Africa. A combination of questionnaires, interviews and classroom observation was conducted. A questionnaire was administered among the 40 randomly selected students from four campuses of EWC, while the interview schedule was conducted with eight lecturers. Classroom observation was conducted with one campus. The questionnaire data was analysed using tables and graphs, while interview and observation data was analysed using content analysis of categories and codings. The results indicated that students register for Engineering drawing without relevant background knowledge of the subject in relation to their trade. Students study the course without Drawing instruments. Drawing lecturers find it difficult to teach overcrowded classes. They teach in classes where Drawing models are not available and students lack motivation. Some of the recommendations includes: EWC should work hand in hand with the parents to assist in getting expensive instruments for the students. Drawing models, charts and other relevant resources need to be budgeted for and be kept in a safer place at each campus.

Introduction

Ekurhuleni West College (EWC) is the name of the cluster after four colleges from the East Rand were merged to form one cluster or college. It consists of the following campuses that were previously known as technical colleges: Kempton, Germiston, Tembisa and Kathorus campuses. All students who enrol for Mechanical Engineering must take Engineering Drawing, as one of their major subjects since it is the main foundation for future mechanical engineers. After the merging process, new admission criteria became effective during the second trimester or from May of 2003 within EWC. All EWC campuses followed the same criteria in enrolling students.

The difference between these EWC campuses is that Tembisa and Kathorus campuses are
the only ones that are based in Tembisa and Katlehong townships respectively. The other two, that is, Kempton and Germiston, are based in towns, Kempton Park and Germiston respectively. Just like any other subjects in an engineering field within a Further Education and Training institution, engineering Drawing N2 is a ten-week course. It is one of the subjects that are recommended when applying for in-service training in a mechanical field.

Drawing N2 gives learners the opportunity to communicate ideas graphically, carry out practical projects and tasks using technological process skill of investigating, designing, making, evaluating and communicating (Department of Education (DoE, 2002:10). During our January 2004 registration period in Kempton campus, some of the students in a mechanical field quit Drawing N2. Some wanted to continue with mechanical subjects, but were not interested in doing drawing.

The following are some of the reasons students gave when deciding on quitting or not doing Drawing N2 at all:

- The experience they got in the previous level (N1).
- The difficulty in understanding Drawing N2 for the first time (after being told by their friends).
- Drawing as unpopular subject in the society.
- The total price of drawing instruments.

Most of our learners in an N2 level are in their late adolescence and early adulthood stage. This creates a big problem, more especially in classroom control. The reason being that in this particular stage, a learner finds himself in a situation whereby his obligations towards learning are replaced by obligations towards the society (Fraser et al, 1993:16). At this stage what the learner is engaged in, in a society, is of more importance as compared to what we expect of him in the classroom.

The learner might be interested in sports, socialisation, etc., and immediately when what he does at school differs completely to what he does in the society, a school becomes a difficult place to be, for him. This creates a big challenge to a teacher who plans the curriculum because whenever the teacher plans the curriculum, he should be aware that the teaching profession serves the community and thus must account to the society for its actions (Vermeulen, 1997:17).

Since the researcher has already mentioned that two of EWC campuses are in townships, there might be a difference in the kind of the society that each campus serves. For example, most of our learners in Kempton campus are from as far as Limpopo, Kwazulu-Natal, and the Free State provinces, while there is only a few from surrounding areas like Kempton Park and Tembisa. So it is very much important for a lecturer to look into his learners drawing background before planning and preparing a lesson (Gunter et al, 1999:14).
At Kempton campus it is not very often that students achieve distinctions in Drawing N2. This does not mean that it is impossible, but when gifted learners attend with slow learners, most of the attention is paid to the slow learners. This in turn disables the stronger learners' performance (Gunter et al., 1999:8). Since everything in class should be outcomes-based driven, a lot of changes must happen in the classroom. The following points are the changes as stated in DoE (1997:27):

- Learners, actively involved in classrooms where the curriculum is relevant and learner-centred, will blossom and grow.
- Learners will have greater self-esteem because they will be allowed to develop at their own pace.
- Learners will be trained to work effectively in groups.
- Learners will become analytical and creative thinkers, problem solvers and effective communicators.
- Learners will understand why they are learning.

This will help teachers establish what kind of talent learners have and how learners develop. However, for teachers to teach in an Outcomes Based Education (OBE) approach, the following are implied (DoE, 1997:28):

- OBE requires teachers and trainers to focus on the outcomes of education rather than merely on teaching information.
- OBE encourages teachers and trainers to translate the learning programmes into something achievable.
- In OBE, teachers and trainers are encouraged to find ways of providing conditions of success in a classroom.

In the meantime, all EWC teaching members attended a one day OBE training course in October 2003 at the Germiston campus. If all lecturers offering Drawing N2 start using the OBE approach in their lessons it will be worth their while. Chapter 3 of this study discusses this further.

Statement of the problem

The Mechanical Engineering department at Kempton campus is the only department with a low student number. The number of learners per trimester at Kempton campus who take Drawing N2 used to be between 50 and 60. Some of the learners have been reluctant to take Drawing N2 since May 2003. The number of N2 Drawing students has dropped to between 40 and 50 students per trimester (as from the second trimester of 2003). The recent academic performance of the N2 Drawing students has also decreased. The following graph shows the performance of learners in N2 Drawing in the previous trimesters:

FIGURE 1.1: Engineering Drawing N2 students' performance (Kempton campus)
The study intends to identify factors resulting in poor academic performance in Drawing N2 students at the other EWC campuses. The investigation will assist in providing a solution to keep the academic performance in Drawing N2 at all the EWC campuses at a satisfactory level.

Purpose of the study

The purpose of this paper is to report on the factors contributing to poor performance of learners in Drawing N2 at Ekurhuleni West FET technical college, Gauteng Province, South Africa.

Research Methodology

The researcher used both the qualitative and quantitative research design methods. Qualitative research is a broad term that encompasses a variety of approaches to interpret research. Qualitative research is used in this study to obtain information through observation and structured interviews. Quantitative research, on the other hand, is a research methodology that seeks to quantify the data and typically, applies some form of statistical analysis (Malhotra, 1996:164). A quantitative-descriptive (survey) design was therefore used which involved the use of questionnaires for data collection (De Vos, 2001:78).

Population and sampling

The population of EWC, comprises of 119 students and lecturers that are involved in Drawing N2/ N3 (110 Drawing students and 9 Drawing lecturers from all the EWC campuses). Out of the 110 Drawing students, 12 of them are N3 Drawing students, that is, three students per campus. The 12 N3 students are those who have passed Drawing N2 the previous term.

- Tembisa campus = 29 Drawing students.
- Germiston campus = 31 Drawing students.
• Kathorus campus = 25 Drawing students.
• Kempton campus = 25 Drawing students.
Probability sampling was used to select 40 Drawing students (36% of the students' population), that is, seven N2 students from each campus and three N3 students from each campus, to participate in the research. Systematic random sampling was used on each campus in order to give every member of the population an equal chance of being selected as part of the sample.

Table 1.1: An indication of the probability sampling used in selecting students.

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>N2 students</td>
<td>7 per campus (28)</td>
<td>70</td>
</tr>
<tr>
<td>N3 students</td>
<td>3 per campus (12)</td>
<td>30</td>
</tr>
</tbody>
</table>

The above table illustrates that seven Drawing N2 students per campus were selected plus the three Drawing N3 students (who have passed Drawing N2) were also selected from each campus.

Data collection and analysis

Questionnaires using the Linkert scale were distributed to gather information from all four campuses.

Eight individual interviews were conducted with Drawing lecturers. Two of these lecturers were from each of the four campuses. Drawing lecturers were chosen for the interview because they are the ones who know exactly what happens in the teaching and learning situation in the classroom. See Appendix C for the interview questions. The interviews did not exceed fifteen minutes and they lasted more than five minutes.

Classroom observations were conducted using the Kempton campus' classroom observation schedule. This schedule was designed by the Kempton campus Management and it is currently used during classroom observation. The primary advantage of conducting observations is flexibility, though the very presence of an outsider in structured observations may alter what people would normally say and do (Leedy & Ormrod, 2001:158). Certain research questions can best be answered by observing how people act and behave during the normal course of their working day. Prior arrangements were made with The Head of Divisions from the four campuses in order to notify Drawing N2 lecturer(s) of the day and time of the classroom visits. Observations were conducted in Drawing classrooms at each campus. A validated and reliable teachers’ evaluation form was used during the classroom observations. The Head of Division of Kempton campus supplied this form. It is a schedule which is used during formal class visits.

Statistical analysis was used to analyse questionnaire data, in the form of graphs, tables and pie charts. Interview data was analysed using content analysis and verbal quotation. In this study, pie charts were mostly used to describe the research sample since they are best suited to display categorical data (Wegner, 1999:29).
Results

Descriptive statistics are used to summarise the data and to make it easier for the reader to understand. It also shows how the sample represented the population. The research sample, which was comprised of the students and lecturers, included more of males than females. All Drawing lecturers were males as they dominate in the Drawing department.

Out of the forty Drawing N2 students who received questionnaires, thirty-seven participants completed and returned the questionnaires. All twelve N3 students’ questionnaires were returned. This constituted a 93% response rate from the students. The researcher personally collected the questionnaires from all participants.

FIGURE 1: Importance of drawing in a mechanical field.

Learners were requested to indicate the extent to which they agree with the importance of drawing in a mechanical field. The responses are shown in Figure 3.3 below.

The above figure shows that the majority of students (64%) see the importance of drawing in a mechanical field. Therefore the remaining 36% can be easily motivated to realise the value of drawing.

FIGURE 2: The environment in which drawing is attended is conducive/ suitable to learning.

The environment for learning should be conducive to learning. Learners were asked the extent to which they agree that their learning environment is conducive to learning. Figure 2 shows the response:
The above figure shows that only 65% of the Drawing students are convinced that the Drawing environments are suitable for learning. The remaining 35% have a serious problem that could result in the poor academic performance.

FIGURE 3: The time schedule for Drawing N2 syllabus.

Students were asked the extent to which they agree that the time schedule for Drawing N2 is enough to complete the syllabus. Figure 3 below shows their response rate:

The above figure shows that 59% of students do find the time allocated for Drawing N2 enough for them to complete all the tasks. This leaves 41% of students not having enough time to complete all the tasks. This could have a serious impact because 41% students will have been used to submitting unfinished projects.

FIGURE 4: The relevance of the Drawing N2 syllabus to the trade subject.

Students were asked to which extent is the Drawing N2 syllabus relevant to their trade subjects. Figure 3.6 shows their response rates:
The above figure shows that 28% of students are not sure about the connection between drawing and the trade subjects. When these students enter for their exams without knowing the relationship between drawing and their trade subjects, their failure rate affects the College.

FIGURE 5: A role that Drawing instruments play in completing Drawing tasks.

To what extent do Drawing instruments play a role in the completion of Drawing tasks? This is how the students responded:

The above response shows that 24% of the students do not fully agree that instruments play a role in passing Drawing N2. The remaining 4% disagree to an extent and this might lead to the other 72% being de-motivated in bringing their instruments to class, because they see fellow classmates not having any instruments at all.
TABLE 1: An illustration of the views of students in the choice of subjects.

Students were asked whether they take drawing because of not having any other option. The following table shows their responses:

<table>
<thead>
<tr>
<th></th>
<th>N= 25</th>
<th>Raw score</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totally agree</td>
<td>19</td>
<td>19</td>
<td>76</td>
</tr>
<tr>
<td>Agree to a certain extent</td>
<td>4</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Disagree to a certain extent</td>
<td>2</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Totally disagree</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The response shows that 76% of the students enrol for drawing simply because they had no other choice. This might result in students not putting more effort into drawing, because they do not see any use in taking drawing.

TABLE 2: An illustration of the views of students on whether their parents have any say in choosing subjects and careers.

Students were asked whether their parents have a say in their subject choice. Table 2 shows their responses:

<table>
<thead>
<tr>
<th></th>
<th>N= 25</th>
<th>Raw score</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totally agree</td>
<td>13</td>
<td>13</td>
<td>52</td>
</tr>
<tr>
<td>Agree to a certain extent</td>
<td>8</td>
<td>8</td>
<td>32</td>
</tr>
<tr>
<td>Disagree to a certain extent</td>
<td>4</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Totally disagree</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2 shows that 52% students totally agree that parents still have a voice in their subject and career choice. This leaves teachers with the task of sharing relevant information on subjects and careers before classes commence.

TABLE 3: Campus resources and equipment for Drawing N2.
Students were asked whether their campuses have the necessary resources or equipment for Drawing N2. Table 3 shows their responses:

<table>
<thead>
<tr>
<th>N=25</th>
<th>Raw score</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totally agree</td>
<td>16</td>
<td>64</td>
</tr>
<tr>
<td>Agree to a certain extent</td>
<td>8</td>
<td>32</td>
</tr>
<tr>
<td>Disagree to a certain extent</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Totally disagree</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The above response shows that 64% totally agree that their campuses have the necessary resources for drawing. But since it is proved in Figure 3.3 that 36% of students do not see the importance of drawing in the mechanical field, they might as well not know the required resources that they need.

**TABLE 4: The affordability of Drawing N2 instruments.**

Students were asked whether they can afford all the necessary Drawing equipment. Table 4 shows their responses:

<table>
<thead>
<tr>
<th>N=25</th>
<th>Raw score</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totally agree</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Agree to a certain extent</td>
<td>11</td>
<td>44</td>
</tr>
<tr>
<td>Disagree to a certain extent</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Totally disagree</td>
<td>6</td>
<td>24</td>
</tr>
</tbody>
</table>

Table 4 shows that most Drawing instruments are affordable to students.

General questions directed to N2 Drawing students about drawing content knowledge.

**FIGURE 6: The need for N1 or secondary level drawing background.**

Students were asked whether a drawing background from the N1 or secondary level is necessary in order to understand Drawing N2. Figure 6 shows their responses:
The above figure shows that the majority of students (72%) need drawing background knowledge on drawing before doing Drawing N2. This shows that students' previous drawing results need to be checked according to the campus admission requirements before they enrol.

FIGURE 7: The Drawing lecturer's knowledge of drawing.

Students were asked whether their Drawing lecturers are knowledgeable in drawing. The figure below shows their responses:

Most students (96%) are satisfied with the knowledge and experience of their Drawing lecturers, as illustrated on the figure above.

TABLE 5: The relevance of exercises and examples in a Drawing textbook.

Are the exercises and examples found in the Drawing N2 textbook practical and relevant to the Drawing N2 syllabus? Table 3.6 shows the students' responses based on the above question:

<table>
<thead>
<tr>
<th></th>
<th>Raw score</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>16</td>
<td>64</td>
</tr>
<tr>
<td>No</td>
<td>9</td>
<td>36</td>
</tr>
</tbody>
</table>
The above table shows that 64% of students are not too worried about the exercises and examples found in the prescribed textbooks. This might be because of the mere fact that because drawing does not make sense to their trade subject, they see no need to be concerned about exercises in the book.

OBSERVATION

A class visit report schedule was used in classroom observation (see APPENDIX D). The researcher was accompanied by the senior lecturers of each campus during classroom observations. The researcher and each senior lecturer from each campus picked up the following during observations:

Lecturers' presentation of the learning content

The lesson presentation was satisfactory because every lesson linked the previous activity with the present activity. Both Drawing lecturers taught on the learners' level of understanding. The language used was clearly understood by all students. Some African language explanation was used for the slow-learners and not in delivering the content since the medium of instruction in the entire college is English. This African language was a blessing to the students with language problems, because it is said on page 21 section 2.5 of this study that an African language is said to be a language of understanding.

The Germiston and Kathorus campuses are the only campuses offering CAD (Computer Aided Draughting). This is a computer program that enables students to draw using a computer. The advantage of this program is that students need to be computer literate in order to draw. And as soon as they are computer literate, then they can finish whatever is given to them very speedily.

The Germiston and Kathorus campuses are the only campuses that have enough teaching media like charts, projectors, Drawing models and advanced transparencies having various colours that explain contents with ease. The students' participation in all four campuses was good, especially in doing the tasks given to them. Some were trying in poor conditions, e.g. where half of the class had no instruments and no display boards (where Drawing models are kept) were used.

Lecturers' preparation of lessons

Lecturers' presentation of lessons showed that they have prepared beforehand. Their confidence and personalities shared the sentiments outlined on page 19 in section 2.4.1, that the teacher's personality and his professional competence are the co-determiners of the meaningful course of the didactic activities. Their preparedness showed that they were familiar with the content and the teaching materials as stated on page 26 of this study, in section 2.9.
INTERVIEWS WITH DRAWING LECTURERS

This section provides a transcribed summary of the interview results with the Drawing lecturers. Similar questions were asked to lecturers using a semi-structured interview schedule.

Time available for lecturing Drawing N2 per trimester

The Germiston and Kathorus campuses are the only campuses that find the time for teaching Drawing N2 sufficient, even for revision. This was said because they offer CAD programmes and they have the necessary Drawing equipment. One lecturer from Germiston said the following after he had been asked if he is satisfied with time available for teaching N2 Drawing:

"Yes, I am, for as long as we can finish the syllabus then I am convinced that time is enough."

One lecturer in Kempton campus said the following after he had been asked whether he is satisfied about the time:

"Time is very short, especially when students take out their Drawing instruments, they are too slow"

The drawing background of the students based on the topic of the day

Lecturers agree that N2 students have the relevant drawing background. After being asked whether his students showed any previous knowledge in drawing, a Tembisa campus lecturer said the following:

"Yes, especially the students who are from N1 and those doing Drawing N2 for a second time, but they showed lack of interest."

If lecturers notice signs of laziness in their classes and ignore it, students will eventually do nothing at all and their results will be affected, because classroom discipline and management can be the cause of poor academic performance as stated on page 24 section 2.7 of this study.

When are students given individual attention?

Lecturers do not have enough time for individual consultations in the drawing class. They say that it depends on the number of students and how many of those students have background knowledge. One lecturer from Germiston campus said the following:

"We normally create another class whenever we have a lot of students; in this sense we avoid overcrowded classrooms and they are easily managed."
On page 29 section 2.10.2 of this study, it is mentioned that at Kempton campus, we enrol up to 37 learners in each class. If 60% of the learners in a drawing class are doing Drawing N2 for the first time, then going from desk to desk to help students will not be easy.

What would you make the ideal duration of the Drawing N2 syllabus?

The Germiston and Kathorus campuses are satisfied with the time available N2 Drawing because they said that if they can include revision, then it is adequate. At the Kempton and Tembisa campuses, they suggest an increase in the hours for teaching Drawing N2. A lecturer from Kempton campus said the following when asked for his personal input on time needed for Drawing N2:

"I wish I could extend the time that we offer Drawing N2, but I think 2 hours would be better from Monday to Thursday, Friday should be used for the students to do revision and tasks."

This proves what was said in this study that before the teacher plans a lesson, he should ask himself questions like: is the learning process appropriate to the students' present skill of development and preferred learning styles? Students at Kempton campus come from rural areas where drawing is not yet fully introduced. Therefore, sufficient time will be of great importance to these learners.

When is the academic performance of students discussed?

The Drawing lecturers meet very often to discuss the students' academic performance. Even though meetings are often held when the results are problematic, these discussions are worth while. After being asked how important these discussions are, one lecturer from Kathorus said the following:

"It helps us improving the way we approach a lesson."

In this way the teacher develops good subject knowledge, good lesson planning and improved teaching skills.

Conclusion and recommendation

The research findings of this study show that there is a lot of factors that result in poor academic performance of Drawing N2 students on both Kempton campus and other EWC campuses. Students enrol for drawing without relevant background knowledge of the subject in relation to their trade. They continue to complete the trimester without Drawing instruments. Drawing lecturers find it difficult to teach overcrowded classes. They teach in classes where Drawing models are not available and students also lack motivation.
Input is needed from industries to make drawing meaningful to the students. This will motivate the students to be motivated and they will know what to expect in the world of work. New campus rules need to be revisited in order to motivate students to study. The admission requirements need to be changed so that students who have passed Grade 10/11 or 12 without having taken drawing are enrolled for an NC(OR) program which is a level before N1.

EWC should work hand in hand with the parents to assist in getting expensive instruments for the students. These instruments will have to be kept safe at each campus. This will reduce the delay that Drawing lecturers mentioned of students wasting a lot of time when taking out Drawing instruments from their bags. Drawing models, charts and other relevant resources need to be budgeted for and be kept in a safer place at each campus.

References


Fraser, W.J., Loubser, C.P. & Van Rooy, M.P. (1993). Didactics for the Undergraduate Student. 2nd ed.. Durban: Butterworths


A Reconnaissance study into Technology teaching practice in Limpopo Province schools

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Abstract

This paper is based on my ongoing DEd study. It intends to report on the progress made to date and research problem identified during the reconnaissance study. The aim for this preliminary research is to ascertain whether the findings conform to the main research question of the overall research. The study focused only on senior phase technology teachers in four identified schools who are teaching grade 8 (eight) and 9 (nine) in Limpopo Province. This investigation entailed the administering of a questionnaire, conducting interviews and engaged in an observation activity. This was a small scale study, for facts finding purposes before the main rollout of Action Research is ensued. It was evident from the study that teachers are incapacitated to teach this learning area. The teachers lack pedagogical content knowledge (PCK) and are not confident in engaging with practical activities, assessment of learners, and compiling technology learning program. It is imperative to engage in an emancipatory paradigm or critical theory as a way to intervene in these challenges as faced by technology teachers.

Introduction

It is obvious that if technology education is introduced as a completely new learning area (subject) in the curriculum of any country it will engender the need for extensive in-service teacher education (Potgieter, 2004:208). Ever since technology education introduction, the teachers are still grappling with its pedagogy and didactic. This was evident during the honours degree pre-service student – teachers who were engaged in their periodical practice teaching in Limpopo Province from University of Limpopo. During student-teachers’ practice teaching evaluation in Limpopo I observed lack of knowledge in teaching and practice of technology by veteran teachers in the field. This lack of knowledge manifested itself in the following areas:

• Policy: Analyzing and interpreting the Technology Learning Area (TLA) curriculum;
• Planning: Helping with the development of the learning programme, work schedule and lesson plans;
• Resources: Creatively utilizing the material resources that are available in those communities for technology projects.

It was further observed that the student-teachers were more knowledgeable about the pedagogy of technology than their assigned mentor teachers. Instead, the student-teachers
turned out to be the ones empowering their mentors. This reversal in empowering activity confirms the national ministry of education declaration that, ‘whilst educators in South African schools are qualified to teach a variety of subjects, many of the educators of Technology are uncomfortable with the pedagogy of technology’ (Department of Education, 2003: 31).

Does this indicate to us that either the in-service of the teachers did not help them or they never have any? The method used to gather data help more to unveil the above question. The study intends to expose what actually courses that lack of knowledge from the technology teachers.

A preliminary study/reconnaissance phase/initial reflection was conducted to verify the research problem that was identified and develop themes based on the responses. Preliminary research is done to ensure that you don’t find out, after putting in a lot of work, that your idea is not a good one for a dissertation (Hofstee, 2006:52; Kemmis & McTaggart, 1988:54)). This investigation entailed the administering of a questionnaire and conducting interviews and observation on senior phase technology teachers in selected schools in Limpopo Province. It was evident from the study that teachers are incapacitated to teach TLA as it was not part of their tertiary course/module in their time. They lack pedagogy content knowledge and are not confident in engaging with practical activities, assessment of learners, and designing of technology learning programmes. The study will contribute in emancipating under qualified teachers in the area of technology education. If this works for Limpopo Province other provinces nationally can adopt and adapt to the procedures used during this action research.

So may studies have been carried out previously by other scholars. They concentrated on other aspects of teaching technology. The previous scholars used different approaches, data collection instruments, focus points and so on. This study is different in a sense that it is a reconnaissance study prior to the full roll out of the main study in Action Research (AR) domain.

Various studies have seen carried out on the impact/INSET/aspects of implementing technology education (Sibisi, 2009; Nziyane, 2009; Nkosi, 2008; Tholo, 2007, Gumbo & Mapotse, 2006; Reitsma, 2006; De Vries, 2006; Nkotsoe, 2004; Makgato, 2004; Ankiewicz 2003; Ankiewicz, 2001; Stevens, 2001; Maluleka, 2000; Gumbo, 2000; Lliadis. 1999; Gumbo, 1998; Drost, 1998; Potgieter. 1996; Kristein, 1996; Fritz, 1996; Frazer 1996, De Vries, 1996). However, little research has been conducted on Action Research with technology teachers. Therefore I attempt to fill that gap.

**Theoretical frameworks**

The foregoing discussion on the need to emancipate technology teachers in the light of critical theory, provides the conceptual framework for a qualitative inquiring which explore whether Action Research can raise teachers’ confidence of teaching TLA. Critical theory is an examination and critique of society and culture, drawing from knowledge across the social science and humanities. Critical social theory is a form of self reflective knowledge involving both understanding and theoretical explanation to reduce entrapment in system of domination or dependence, obeying the emancipator interest in expanding the scope of outcome and reducing the scope of denomination (Wikipedia critical theory, 2010).

The complexity of implementing technology education is well portrays by Pudi, (2007: 34) in citing that of the eight learning areas in Curriculum 2005 (C2005), technology
education is something completely new. Unlike the other learning areas whose etymology can be traced to the previous education dispensation, technology education began with the inception of C2005. Because of its newness, technology education is prone to misunderstanding, misinterpretation and, to some extent, resentment. It will be therefore imperative to use critical theory to examine and critique technology teachers in their classroom teaching practices since there will be self reflective practices for change if AR methodology is incorporated.

Dick (2010: 4) point out that as the names of AR suggest, is a methodology which has the dual aims of action and research...

- Action to bring about change in some community or organisation or program
- Research to increase understating on the part of the researcher or the clients or both

There are in fact action research methods whose main emphasis is on action with research as a fringe benefit. It is therefore the intention of this study to bring about change in technology didactic and increase understanding in technology implementation. The activities of action and research will be exercised by taking into cognisance the succinct explanations which state that AR is known by many other names, including participatory collaborative inquiry, emancipatory research, action learning, and contextual action research. Action research involves utilizing a systematic cyclical method of planning, taking action, observing, evaluating (including self-evaluation) and critical reflecting prior to planning the next cycle. AR is a reflective process of progressive problem solving led by individuals working with others in teams or as part of a "community of practice" to improve the way they address issues and solve problems (Carr & Kremmis, 1986; Kemmis & McTaggart, 1988; McTaggart, 1989; Kemmis & McTaggart, 2000; O’Brien, 2001; McNiff, 2002; Hofstee, 2006).

This study attempts to answer the research question stated as follows: ‘How can preliminary enquiries into technology teaching practice yield information to support the main research question of the study?’ The aim of this reconnaissance study is to confirm the research question by engaging in fact-finding activities with the participants. Let us then join in a round table discussion to share the findings, hoping that this will pave a way forward for this action research study.

Research design and methods
To address the research problem, an inquiry using a qualitative approaches was undertaken to ascertain the didactive challenges encountered by technology learning area teachers (around technology: lesson presentation, support, resources, project assessment and policy interpretation and implementation) with a view to improve the situation collectively with the participants as co-researchers in the light of action research. I used an action research approach and employed a variety of data-gathering methods, including observation, structured interviews and administering of qualitative questionnaires to understand the internal dynamics of teaching and learning technology within this small scale sample of technology teachers in Limpopo Province.

Table 1: Selected sample schools of MNG Circuit
Denzin and Lincoln (2003:3) contented that qualitative research studies things in their natural settings, attempting to make sense of, or to interpreted phenomena in terms of meanings people bring to them, so shall it be with this current study. The participants and I were together involved in management of technology activities in search for alternative meaning to the current situation.

After permission to conduct the research at MNG circuit was granted by the provincial government, I approached the circuit manager whom we sat and discussed my intention. The circuit manager gave me a list of schools to embark on my investigation based on the diverse location of the schools. The chosen schools are MK, MV, MR and MB as displayed in table 2. He then called on the principals to alert them of my coming. I presented my schedule to him. The circuit and the schools were chosen on the basis that I have observed the lack of PCK within them as highlighted earlier in the introduction.

Qualitative designs are not pre-determined but emerge during the investigation and are matched to the conceptual of the research (Sibisi, 2009:4). I used questionnaire, structured interviews and observations to collect data. The three methods were used for triangulation purposes. These were used in all four schools I visited. The schedule of my visits was as follows:

**Table 2: Schedule of school visit**

<table>
<thead>
<tr>
<th>SCHOOL NAME</th>
<th>DATE OF VISIT</th>
<th>DAY OF VISIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>MK</td>
<td>08/03/2010</td>
<td>Monday</td>
</tr>
<tr>
<td>MV</td>
<td>09/03/2010</td>
<td>Tuesday</td>
</tr>
<tr>
<td>MR</td>
<td>10/03/2010</td>
<td>Wednesday</td>
</tr>
<tr>
<td>MB</td>
<td>11/03/2010</td>
<td>Thursday</td>
</tr>
</tbody>
</table>

All visits were the whole day per school hence I was able to employ all the data collection instruments. The following activities were undertaken per school during the day of my visit:

- Meet school SMT and provide them purpose of my visit
Meet only with technology teachers let them sign a consent form after they agree to be participants

Engage in a class observation during Technology class

Interviews were held in between the periods with the teacher who are free

The teachers were given a questionnaire to fill during their own time and bring it after school to me.

**Data analysis**

The qualitative questionnaires were analysed using the statistical packages for social science (SPSS) in its simplest format. Pertaining to the observation, a grid was prepared prior to class visit for recording and structured interviews was done on a prepared printed schedule as the method was successfully used in conducting school survey for the Plowden report in the UK (Mapotse, 2001: 159). I numbered the prepared coded interviews schedule based on the school e.g. MKIP=1 & MKQR=1, this means that the teacher [ = 1] is from school MK and has acted as interview participants (IP) and responded to a questionnaire (QR).

**Table 3: General biographical information of participants**

Technology in rural areas refers to the context where the participants are teaching and Technology lessons plan question seeks to find out whether participants are able to draw up a lesson plan.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Technology Teaching Experience</th>
<th>Technology Qualification</th>
<th>Technology in Rural Area</th>
<th>Technology Lesson Plans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Female</td>
<td>&lt; 6 yrs</td>
<td>&gt; 5 yrs</td>
<td>Yes</td>
</tr>
<tr>
<td>Frequency</td>
<td>7</td>
<td>9</td>
<td>11</td>
<td>5</td>
</tr>
</tbody>
</table>

The nature of the study is such that a variety of data gathering techniques was used. As a result questionnaires were designed for and administered to teachers of technology education in senior phase, i.e. grades 8 and 9 as listed in table 1. The same participants, sixteen (16) in total, were interviewed and observed. Based on the use of triangulation technique, the questionnaire does not take a uniform pattern throughout. It is flexible and it combines both the closed-ended and the open-ended structures. Triangulation seeks convergence, corroboration, correspondence of results from different methods (Burke & Christensen, 2004: 423).

**Research findings and discussion**

Questions asked in both the interview and the questionnaire responses cover the following:-
<table>
<thead>
<tr>
<th>Item</th>
<th>Interviews section</th>
<th>Questionnaires section</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Policy related</td>
<td>[B]</td>
<td>[E]</td>
<td>No policy documents</td>
</tr>
<tr>
<td>2 Materials / Resources</td>
<td>[C]</td>
<td>[D]</td>
<td>No learners project on display; No tools; No workshop infrastructure</td>
</tr>
<tr>
<td>3 Assessment in Technology</td>
<td>[D]</td>
<td>[C]</td>
<td>No assessment guide from the teachers file</td>
</tr>
<tr>
<td>4 Support</td>
<td>[C]</td>
<td>[D]</td>
<td>No support from smt, and circuit</td>
</tr>
</tbody>
</table>

The letters written in the table indicate the same question asked differently in the data collection instruments. For an example, under policy related question, from the interviews [B] had three questions which read as follows: 1. What is the difference between Technology and Technology Education? 2. What does Learning Outcome (LO)3 addresses? 3. Why LO2 is key in teaching Technology Learning Area? 4. Can you regard LO1 as the method of teaching Technology? The questionnaire on [E] has the following question, ‘Use the Likert scale t reflect your opinion in the interpretation of Technology learning outcomes (LOs). The scale vary from 1- strongly agree to 1 – strongly disagree. The pattern will be the same for all the remaining items. Technology didactic refers to Table 5.

The table below is the combination of the questionnaire responses from all the participants. I asked them to apply constant sum scale to allocate 100 points to technology didactic attributes according to their importance in their planning. The attributes were as follows: Lesson Plan; Learning Programme; Policy documents; Work schedule; Textbook. Findings from the questionnaire: A highest number of seven (7) that is 43.75% from table 5, indicated that they would prefer to use both the text book and the policy documents as their tools for their planning.

Table 5: Teachers’ technology didactic attributes
<table>
<thead>
<tr>
<th>Items</th>
<th>didactic</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>Row Pct</td>
<td>&lt;10%</td>
<td>16-20%</td>
</tr>
<tr>
<td>Lesson planning</td>
<td>1</td>
<td>6.25</td>
</tr>
<tr>
<td>Learning programme</td>
<td>2</td>
<td>12.50</td>
</tr>
<tr>
<td>Policy document</td>
<td>2</td>
<td>12.50</td>
</tr>
<tr>
<td>Work schedule</td>
<td>2</td>
<td>12.50</td>
</tr>
<tr>
<td>Textbook</td>
<td>1</td>
<td>6.25</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>20</td>
</tr>
</tbody>
</table>

Five questions were asked that relate to technology didactics during interview with the participants. **First**: What is the difference between technology and technology education? **Second**: What does Learning Outcome 3 (LO3) addresses? **Third**: Why LO2 is vital in teaching technology? **Fourth**: Can you regard LO2 as a method of teaching technology? Support your answer. **Fifth**: With whom and when do you plan your Learning Programme?

These are how the participants’ responded to the above two questions. Interview Participants (IP) responses;

**MKIP – 05**: respond to question 1--- Technology Education deals with theory and Technology deals with practical. Here at MK high we focus on theory.

**MKIP – 03**: respond to question 2--- ‘Not sure I have not seen the policy document so far’;

**MVIP – 03**: respond to question 3---‘ Not sure’;

**MKIP – 06**: respond to question 4---‘I don`t know the LOs by heart I have to refer’;

**MKIP -07**: respond to question 5---‘Alone’

Findings from the interview responses: Teachers seem not to be clear on how to differentiate technology from technology education. They don’t what technology LOs addresses as well as how to apply them. They don`t develop a learning program together. **Findings** from observations: As I was doing observation among technology teachers from all four schools, only one (MB high) out of four schools have some textbooks. It’s a
pity because even when they have at least textbooks they still say LO3 is for designing.

Assessment in Technology.................................................................refer to Figure 1

There were similar general questions asked during the interviews as well as from the questionnaires. Same participants were required to respond to both. Only five questions were asked during the structured interviews:-

1. What are we assessing in technology? 2. What forms of assessment do you incorporate in your technology didactic? 3. Are learners accorded an opportunity to discuss assessment instrument prior to its implementation? 4. Do you have provincial or national guide to assessment? 5. How long is your turnaround time after your learners have submitted their tasks?

Sample of assessment interview responses from participants based on the five (5) questions asked are as follows:

MKIP – 02: respond to question 1---‘We asses skills and evaluate knowledge’;

MVIP – 02: respond to question 2 ---‘Tests & exams, assignments, group activities, projects and posters or collage’.

MRIP – 02: respond to question 3 ---‘No, if there should be a discussion it is no conducive as it just a waste of time’.

MVIP – 02: respond to question 4 ---‘No, since there is no technology curriculum adviser’.

MRIP – 02: respond to question 5 ---‘Class works two weeks, tests also two weeks’.
Findings from interviews: I realised that class/home works as well as group activities are also used as an assessment tools. At least there are technology teachers from one school (MV high) who use quite a variety of assessment tools. Teachers offer no prior assessment discussion to the learners. They don’t have assessment guide booklet from both national and provincial. Seemingly, teachers don’t know actually what is supposed to be assessed and exactly what is expected of them to evaluate.

Responses from the questionnaire are indicated in figure 1 above. The technology teachers were supposed to endorse the rank order scale to rank the assessment they use during technology teaching in their order of importance. The ranking list should apply to, Assignments; Portfolio; Projects; Collage; Tasks; Tests/Examinations.

Findings from the questionnaire: Nine (9), that is 56.25% out of sixteen (16), rank order1, prefers tests/examinations as the best assessment strategies. During observation this was true as all schools give monthly tests to learners. Based on teacher: learner ratio the turnaround time at most is two weeks. Only equal number of seven (7) in each category share the sentiments that both portfolio and project can be used as assessment tools, rank order 2 and 3 respectively.

Figure 1: Assessment in Technology
Support in Technology.................................................................refer to Figure 2
The respondents were supposed to engage in a comparative rating scale for their technology support they receive from the following stake holders, 1. School and 2. Colleagues. 3. The respondents were once again requited to compare both the policy
document to text book, indicating which one they can understand and implement with ease. The fourth and last question: The respondents has to confirm whether they are familiar with the how of developing learners task as compared to using technological process to develop projects.

Figure 2: Support in Technology
The responses scales range from much better to much worse. Findings from the questionnaire: Around 62.5% of teachers have indicated that they are getting much worse support from both circuit office as compared to their schools, those are 10 out of 16. About 50% of the technology teachers indicated that they can use policy document as compared to a textbook.

Findings from the interview: Teachers or participants were asked whether they do projects with their learners and which theme are they comfortable to teach, respond from MKIP – 07 said ‘Yes’ projects under the comfortable theme are done and the comfortable theme is Structures. If asked where they get their materials to do their projects, mostly responded by saying the school does supply the and the rest of the resources/materials learners have to fend for themselves. From my Observation there is no school with any technology workshop or tools to help both teachers and learners to do some projects.

Learning Outcomes in technology ..............................................................refer to Table 6
Table 6: Learning Outcomes in technology

<table>
<thead>
<tr>
<th>Items</th>
<th>strongly disagree</th>
<th>disagree</th>
<th>undecided</th>
<th>agree</th>
<th>strongly agree</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Row Pct</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teachable/unreachable</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>Neg/pos participation</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>Understandable/not clear</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>3</td>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td>Easy/difficult to follow</td>
<td>0</td>
<td>1</td>
<td>7</td>
<td>3</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>Theoretical/practical</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>Context/content</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td>5</td>
<td>16</td>
</tr>
<tr>
<td>Test/exam driven</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>Clustered/well structured</td>
<td>0</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>12</td>
<td>31</td>
<td>42</td>
<td>33</td>
<td>127</td>
</tr>
</tbody>
</table>

Frequency Missing = 1

The respondents were asked to use a Likert scale of 1 to 5 to reflect their opinion in interpretation of technology learning outcomes. The scale ranges from strongly agree to strongly disagree. From table 6, one could see that 9 out of 16 strongly agree that the LOs are teachable and the 7 out of 16 respondents agree that the learning outcomes are clustered.

There is also the same number of teachers that is 7 out of 16 which is 43.74%, the first ones are saying the LOs discourages participation and the same number says is undecided whether the LOs are understandable.

Conclusion
The main question of my DEd study is: “How could Action Research intervention be used to improve the teaching practices of senior phase technology learning area teachers who are under qualified to teach technology education?” whereas the research question for this SAARMSTE 2011 conference paper is: “How can preliminary enquiries into technology teaching practice yield information to support the main research question of the study?”

Readings from the findings it is clear that this preliminary enquiry into technology teaching practice has yielded overwhelming information to support the question of the main study. An intervention in the form of Action Research will most probably change the situation as it is now. Technology teachers who were both questionnaire respondents and interview participants in this study will be emancipated to develop in the following areas:-

- To stop working in silos and team up together to draft things like a learning programme;
They should really the genesis of technology and the National Ministry of Education has introduced that in the curriculum;

Technology Policy: Technology teachers should be able to analyze, interpret and implement Technology Learning Area (TLA) curriculum;

They should incorporate other assessment tools in their technology classes;

They should be exposed to technology planning that is helping them with the development of the learning programme, work schedule and lesson plans;

Unless they are empowered to teach technology contextually they will never be able to creatively utilize the material resources that are available in their communities for technology projects.

Recommendations
As a main researcher who has done a preliminary reconnaissance investigation with my co-researchers (technology teachers) as part of my entry into Action Research, I have realise the all teachers from all schools they have the same challenges. We need to involve ourselves in utilizing a systematic cyclical method of planning, taking action, observing, evaluating and critical reflecting in the didactic of technology. AR will be the best practice to embark on with the sole purpose of engaging in a reflective process of progressive problem solving so as to improve the way technology education is taught and solve problems relating to TLA together. Technology teachers need to be supported with tools, materials and relevant books every step of the way.

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Perceptions of student teachers at the North West University (Mafikeng Campus) about the importance of technology education

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Introduction
Since the introduction of Outcomes-Based Education (OBE) in South African schools, a number of changes have taken place in the composition and structure of the curriculum. Technology was introduced as a compulsory learning area from Grade R up to grade 9 as part of the education transformation process. Technology education was introduced to enhance learners’ technological literacy so as to enable them to develop and apply skills.
that will enable them to solve technological challenges and problems (DoE, 2002). This development brought with it a number of challenges and constraints in the school’s curriculum. Chief among these challenges was the lack of properly trained educators in the learning area compounded with a lack of the requisite teaching and learning materials (Jacobs, 2005). Teachers who taught the subject at schools were either under qualified or unqualified.

Schools were forced to have stop-gap measures in place to fulfill the new requirements for the inclusion of technology in the curriculum. The teachers who were made to teach the subject had little or no experience in technology teaching. Technology was therefore not taught in its proper context. Technology education therefore continued to be handled in a haphazard way (Stevens, 2005). Most educators who were tasked to take the technology classes were not comfortable in teaching the learning area but had little or no option except just to carry out the duties.

In response to the need for more qualified technology educators, tertiary institutions like the North West University through the Faculty of Education re-aligned its teacher training programmes to include technology education in the curriculum as a compulsory module. This intervention was greeted with divergent views among the student teachers. This is not without cause because prior to the introduction of technology education, many people had treated and continued to treat technology education as second rate and had underrated its importance in society. Some student teachers were therefore not completely satisfied with the inclusion of technology in the curriculum. There are still people who also consider technology education as a “boy- subject” (Sanders, 2005). This paper therefore tries to explore the perceptions of the student teachers towards the inclusion of technology in their studies.

Literature
According to Pudi (2008: i), technology has a role to play in culture and society besides its importance in education. It is imperative that the learners are made aware of the nature of technology and its existence in their own cultures and societies so as to dispel certain myths about it being elitist. Khumalo (2006) also says that technology education is also very important as it caters for academic, political and social purposes for transformation in the South African perspective. This implies that technology education plays a multifaceted role in our societies, country and the world at large. Technology finds unlimited applications in important areas such as the production of medicines, telecommunications, e-learning and defense and security to safeguard territorial integrity of nations.

A lot of work needs to be done in promoting technology education since there are a lot of grey areas especially when it comes to its literacy and importance in our daily lives. Most people perceive technology to be synonymous with science and that “technology” is inferior to “science” since science always appears first before technology in many terms (Heptinstall, 1996). These are typical notions that we find in the majority of people and there is need to clear such misconceptions. As affirmed by Kuiper (1996), technological literacy addresses concerns about relevance of technology since technological developments have gained importance in our modern societies and therefore learners should be taught to work with these developments.
A number of people think that there are innate differences between boys and girls in relating to technology and believe that boys are more capable in grasping technological concepts than girls (Riggs, 1997: 219). This unfortunate misconception often becomes embedded in people’s minds. However, research shows that one of the main reasons for the strengthening of this misconception is that girls are normally not given the same kinds of opportunities to be technological skilful as boys (Ching et al, 2000: 68). Another challenge that technology education faces in South Africa is the attitude of the teachers which has been recorded as negative towards the learning area and which causes learners to follow suit (Pudi, 2008: 261).

Methodology
Quantitative techniques were used to gather research data from third year Bachelor of Education (B Ed) degree and Postgraduate Certificate in Education (PGCE) students. A structured questionnaire was administered as a research instrument to the students. The questions were on technological literacy, the technology environment, the uses of technology, employment opportunities, gender bias, technology and teaching, and technology as a past time.

The population was made up of ninety-six (96) students who also served as the sample. Data was analysed using simple percentages, graphs and tables.

Results
Details of Participants
Participants were mainly female (54%) in the 20 to 35 years old group (48%) studying towards a BEd degree (33%). Only 27% of the respondents have either Technology or Computer Applications Technology as one of their major subjects in their studies. All BEd students who have either Technology or Computer Applications Technology as one of their major subjects are male and for PGCE students, 85% of the students who have either Technology or Computer Applications Technology as one of their majors are female.

Technology literacy
92% of the respondents indicated that technology literacy should be promoted during teacher training programmes. Only 4% and 4% of the respondents were “not sure” and “disagreed” respectively with the notion of the inclusion and promotion of technology literacy during teacher training.

Technological environment
On the technological environment, 62% of the respondents indicated that working with or in technology was not dangerous whilst 13% suggested the contrary. 25% of the respondents were not sure about whether working in a technological environment was dangerous or not.

Technology uses to people
As shown in figure 1, 94% of the respondents concurred that everybody needs and uses technology. Only 6% of the respondents were not sure of the need and uses of technology to humans.

![Bar chart showing the need for technology](image)

**Figure 1: The need for technology**

**Employment opportunities in Technology**
When participants were asked about employment opportunities in technology, 82% of the respondents indicated that there were good employment opportunities in technology whilst 6% thought otherwise. 12% were unsure about job opportunities in technology.

**Role models in Technology**
For technology education to be successfully promoted there is undoubtedly need for role models that will inspire the learners to have the quest to venture into the field. When asked if they knew about role models in technology education and related occupations, 54% of the respondents indicated that there were role models in technology whilst 27% were not sure of the presence of role models in technology.

**Gender bias**
On gender bias, 42% of the student teachers believed that boys are not better than girls in carrying out practical work while 29% indicated otherwise. The other 29% were not sure of any gender biases in technology.

**Use of technology in teaching**
On the use of technology in teaching, 96% of the respondents indicated that teaching with technology should be interesting whilst 4% of the respondents were either not sure or disagreed with the statement.

**Reading technological magazines and literature**
When the student teachers were asked about whether they liked reading technological magazines, 64% of them indicated that they liked reading technological magazines and literature. However, as shown in figure 2, 21% were not sure and 15% showed that they were not interested in reading technological magazines and literature. Almost all respondents (88%) who indicated that they were not interested in reading technological magazines and literature were male.

Discussions and Conclusions
Discussions and conclusions are based on the findings of the themes that were tested, i.e. Technological literacy, the technology environment, the uses of technology, employment opportunities, gender bias, technology and teaching, and technology as a pastime. Our conclusions should therefore go to indicate the perceptions of the students about the subject only, no speculations. Use figures to support argument.

Modern day educators should be good consumers of technology as they require it for various purposes and reasons. Chief among the reasons is that almost all facets of education utilize technology and technological products in one way or another and thus it is imperative that the educators be technologically literate so as to effectively and efficiently deliver in their classrooms.

From this study, it is heartening to find out that gender no longer plays a part in learning technology as most female respondents showed a more positive attitude towards technological literacy. A worrying observation is that a significant number of the respondents (predominantly male) still believe that boys are better than girls in doing practical work. Therefore, there is need to dispel this myth and encourage all learners to take up courses in technology regardless of their gender.

92% of the respondents supported the notion that technological literacy should be promoted in schools. Given the role that technological literacy plays in this modern day not only in education but in all spheres of life, the responses of the student teachers were encouraging.
From the results, 62% of the respondents indicated that working in technological environments is not dangerous but a sizeable number of the respondents (13%) thought otherwise. The results suggest that a good number of student teachers are not conversant with the various technological environments that we live in. This calls for more intense effort in stepping up technological literacy amongst student teachers as their technological literacy plays a vital role in moulding future technologically literate citizens.

As shown in Figure 1, the respondents showed that they are fully aware of the need for technology in our daily lives since 94% of them concurred with the statement that everybody needs technology and that there are good employment opportunities in the various technological fields. Since educators are expected to give career guidance to their learners, it is encouraging to note that the vast majority of the future educators know that technology education is a gateway to numerous well rewarding careers and this will no doubt inspire the young learners to strive for success in the learning area.

On the issue of role models in technology, it was worrying to find out that 56% of the student teachers were either unaware or disagreed with the statement that “there are role models in technology”. This further reiterates the need for intensive technology education within teacher-training institutes.

Concerning the effect of gender in technology, 27% of the participants who were all female supported the notion that boys are better than girls in technology practical work whilst 73% did not agree to this. The result reminds us that there is still need to sensitize female learners that technology and related practical activities are not for boys only but that females are also capable of using their motor skills to produce relevant artifacts.

Almost all respondents (94%) agreed to the statement that using technology in teaching should be interesting. This is quite encouraging to note that the majority of the student teachers are aware of the importance of the use and inclusion of technology in the teaching fraternity. The use of technology in teaching and learning environments certainly empowers learners and thus positively contributes to their success (Berger & Cretchley, 2005).

From figure 2, 15% of the student teachers indicated that they are not interested in reading technological literature and magazines. It was further observed that 88% of those respondents who were not interested in reading technological magazines and literature are male. These results show that a significant number of male student teachers have a negative attitude towards technology. This could be attributed to the lack of technological literacy in some of the respondents.

From the findings of the study, the researchers concluded that there is great need for technological literacy amongst student teachers. It was further noted that some strides are being taken in certain aspects of technological literacy such as the need for technology in everyday life but still a lot needs to be done. There is still need to demystify the notion that technology is a preserve for male students only as some quarters of the student teacher population believe.
References


The mentor-student teacher interaction in times of major curriculum change: Views on the nature of professional support

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289
Between schools and teacher education institutions, the assumptions on the role of school placement in initial teacher education may vary considerably. In order to align such views, and provide baseline data for reform-based teacher education strategies, this study explores the views of student teachers and their school-based mentors about the nature of the professional support provided and received during school placement. Frequency counts, and mean scores of responses to an adapted version of the Likert-scales Mentoring for Effective Primary Science Teaching questionnaire suggest a high level of support across five subscales, reported by both mentors and mentees. Mentors report they provide limited support for subject content knowledge and the implementation of curriculum changes, thus opening possibilities for reform-based teacher education.

Introduction

Teacher preparation, normally, is organised as collaboration between tertiary institutions and schools. Many South African teacher education universities promote the model of the reflective practitioner (Schön, 1987) for the preparation of their student teachers, including for the teacher placement component. However, the loose relationship between South African schools and universities may allow, in practice, for different views on the role of teaching placement. For instance, a common perception amongst school personnel is that learning during school placement takes place according to the cognitive apprenticeship model (Collins, Brown & Newman, 1989): the experienced teacher, or mentor, models exemplary practice, and socialises the novice into the discourse of teaching.

The South African science curriculum has undergone major changes with the introduction of an outcomes-based curriculum framework, and the inclusion of, for instance, critical thinking, the nature of science and indigenous knowledge systems (DoE, 2004). A new wave of curriculum innovations is expected shortly. The teacher education university which is the locus of this study has taken a leading role in curriculum renewal, particularly in the development of materials and strategies for teaching critical thinking (Scholtz, Braund, Hodges, Koopman & Lubben, 2008). This expertise has been integrated systematically within the teacher preparation programme, potentially changing the balance of expertise between mentor and student teacher (or mentee) during teacher placement (Zeichner & Ndimande, 2008). A reforms-based model for teacher placement is being explored with the student teacher perceived as an agent of change (see, for instance, Wang & Odell, 2007). Whereas traditional apprenticeship and reflective practitioner models would only provide support by the experienced teacher for professional growth of the student teacher, a reforms-based teacher education model provides additional support in the reverse direction, from the student teacher to the experienced teacher (for more detail see Sadeck, Scholtz, Braund & Koopman, in these proceedings).

For the alignment of expectations of university-based teacher educators and of school-based educators regarding the role of teacher placement, and also as a baseline for any changes in this role towards adopting a reforms-based model, it is crucial to survey the perceptions of student teachers (mentees) and supporting teachers (mentors) of the nature of professional support during the current, traditional, school placement. This study thus
addresses the following questions:

1. What are the views of mentees on the nature of the support they receive for their professional development from their mentors?
2. What are the views of the mentors on the nature of support they are able to provide to mentees?
3. To what extent do the views of mentees and their mentors correspond?

Methods

The survey study used a sample of 107 volunteering biological science, physical science and technology student teachers, and 22 of their mentors. This paper reports the views of the group of 22 mentors and the mentees they supported.

Questionnaire data were collected from mentees and mentors at the end of a 3-months school placement in the student teachers’ final year. The high-reliability Mentoring for Effective Primary Science Teaching (MEPST) questionnaire (Hudson, Skamp & Brooks, 2005) was adapted to cater for South African (rather than Australian) student teachers and for secondary (rather than primary) school settings. The item adaptations were informed by modifications suggested by Mudavanhu and Zezekwa (2009) in their study of mentor support during teaching placement in Zimbabwe. In addition, peer validation of the appropriateness of the item-terminology for the South African educational context suggested changes in several terms. Two parallel versions of the questionnaire were constructed, one for mentees and one for mentors.

The questionnaires include 45 Likert-scale items with options varying from strongly agree; agree; uncertain; disagree; or strongly disagree. The items probed views on the support in five areas of professional growth: improving student teachers’ personal characteristics (10 items); strengthening their subject content knowledge (7 items); and pedagogical knowledge (12 items); modelling good teaching practices (9), and developing reflective practices (7). The allocation of 34 items to these five sub-scales follows the factor analysis by Hudson et al. (2005) and the remaining items have been allocated, based on ‘logical fit’ rather than statistical evidence.

Relative rating of the items through calculating means and standard deviations was used to establish the perceived nature of mentor support. A simple t-test establishes the significance of differences between views of mentees and their mentors.

Findings

Supporting the development of personal characteristics

Table 1 summarises the views on mentorship support with regard to developing personal characteristics of the mentee. The table includes a list of condensed item statements, the percentage of responses agreeing or strongly agreeing with the statement (%A), and the mean ranking (M) and its standard deviation (SD) for all responses in the group. Finally, the p-values are given for differences between responses from mentees and mentors. A p-value above 0.05 indicates no significant differences.
Table 1: Mentees’ and mentors’ perceptions about developing personal characteristics

<table>
<thead>
<tr>
<th>Qu</th>
<th>The supporting teacher:</th>
<th>Mentees</th>
<th>Mentors</th>
<th>diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Increased confidence to teach the subject</td>
<td>78</td>
<td>4.1</td>
<td>0.9</td>
</tr>
<tr>
<td>9</td>
<td>Encouraged to teach the subject</td>
<td>87</td>
<td>4.1</td>
<td>1.0</td>
</tr>
<tr>
<td>24</td>
<td>Was comfortable in talking about subject teaching</td>
<td>78</td>
<td>4.1</td>
<td>0.7</td>
</tr>
<tr>
<td>27</td>
<td>Was approachable</td>
<td>72</td>
<td>4.0</td>
<td>1.0</td>
</tr>
<tr>
<td>30</td>
<td>Addressed anxieties about teaching the subject</td>
<td>63</td>
<td>3.7</td>
<td>0.9</td>
</tr>
<tr>
<td>32</td>
<td>Instilled positive attitudes in teaching the subject</td>
<td>88</td>
<td>4.1</td>
<td>1.0</td>
</tr>
<tr>
<td>37</td>
<td>Allowed me to teach the subject as often as wanted</td>
<td>72</td>
<td>4.1</td>
<td>1.1</td>
</tr>
<tr>
<td>39</td>
<td>Improved my confidence in teaching the subject</td>
<td>89</td>
<td>4.2</td>
<td>0.6</td>
</tr>
<tr>
<td>41</td>
<td>Allowed flexibility in planning teaching</td>
<td>72</td>
<td>3.9</td>
<td>1.0</td>
</tr>
<tr>
<td>43</td>
<td>Listened when discussing teaching practices</td>
<td>78</td>
<td>3.8</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Overall subscale : Personal Characteristics</td>
<td>78</td>
<td>4.0</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Table 1 shows that the majority of mentors and mentees are positive about the processes of mentoring where these concern the strengthening of personal characteristics. There is however an overall 10% difference in level of positivity in favour of mentors. Mentors think they more strongly support the development of professional–personal characteristics than these mentees are prepared to give them credit for. In four statements mentors were almost universally positive that they carried out these functions whereas about a quarter of mentees did not recognise these attributes in their experiences:

- Talking about subject teaching
- Being an approachable mentor
- Allowing flexibility in planning teaching
- Listening when discussing teaching practices

These are all important professional and personal characteristics that affect relationships between mentees and mentors in school practice. Particularly, good mentoring requires developed and extensive professional conversations about the subject matter and how it
might be translated into meaningful learning experiences for learners. If mentors are not prepared to talk about subject teaching, or to listen to the problems that mentees have in doing this, the process is at best devalued and at worst dysfunctional.

**Developing subject content knowledge**

Table 2 provides a summary of the views of both groups regarding the support for developing subject content knowledge.

**Table 2: Mentees' and mentors' perceptions for developing subject content knowledge**

<table>
<thead>
<tr>
<th>Qu</th>
<th>Supporting teacher:</th>
<th>Mentees</th>
<th>Mentors</th>
<th>diff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>% A</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>1</td>
<td>Displayed subject content expertise</td>
<td>94</td>
<td>4.3</td>
<td>0.6</td>
</tr>
<tr>
<td>5</td>
<td>Discussed the aims of teaching the subject</td>
<td>76</td>
<td>4.1</td>
<td>0.7</td>
</tr>
<tr>
<td>6</td>
<td>Helped with most recent curriculum demands</td>
<td>78</td>
<td>4.1</td>
<td>0.7</td>
</tr>
<tr>
<td>10</td>
<td>Discussed school policies for subject teaching</td>
<td>67</td>
<td>3.7</td>
<td>1.1</td>
</tr>
<tr>
<td>17</td>
<td>Explained the subject curriculum documents</td>
<td>67</td>
<td>3.6</td>
<td>1.1</td>
</tr>
<tr>
<td>22</td>
<td>Discussed knowledge needed for teaching the subject</td>
<td>71</td>
<td>3.7</td>
<td>1.0</td>
</tr>
<tr>
<td>26</td>
<td>Assisted with the university assignment</td>
<td>81</td>
<td>4.0</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Overall subscale: Subject Content Knowledge</td>
<td>76</td>
<td>3.9</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Neither mentees nor mentors are as positive about the support provided for subject content knowledge as they were about the support for personal characteristics. This is the only sub-scale where mentors are markedly more pessimistic than mentees, particularly about helping appreciate the nuances and content of curriculum documents and school policies for subject teaching (see items 5, 6, 10, 17, 22). This probably reflects confusion and turbulence amongst teachers over the status and meaning of the OBE and NCS.

The higher proportion of mentees perceiving this support to have happened might indicate confusion in mentees minds between support with knowledge of the aims and objectives of specific teaching, and knowledge of the wider philosophical and pedagogical standpoints that underpin the educational purposes of the subject itself. This is a finding that has implications for the design of the university course as well as the training of teachers who support students.
Developing pedagogical content knowledge

Table 3 summarises the views of both groups on support provided in order to develop pedagogical knowledge.

**Table 3: Mentees' and mentors' perceptions of developing Pedagogical Knowledge**

<table>
<thead>
<tr>
<th>Qu</th>
<th>The supporting teacher:</th>
<th>Mentees</th>
<th>Mentors</th>
<th>diff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>‰A</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>7</td>
<td>Discussed my planning for teaching the subject</td>
<td>72</td>
<td>3.9</td>
<td>0.9</td>
</tr>
<tr>
<td>8</td>
<td>Guided me with subject teaching preparation</td>
<td>82</td>
<td>4.2</td>
<td>0.8</td>
</tr>
<tr>
<td>12</td>
<td>Assisted me with classroom management strategies</td>
<td>82</td>
<td>3.9</td>
<td>0.7</td>
</tr>
<tr>
<td>13</td>
<td>Gave me clear guidance for planning teaching</td>
<td>82</td>
<td>3.9</td>
<td>0.7</td>
</tr>
<tr>
<td>14</td>
<td>Assisted with implementing teaching strategies</td>
<td>61</td>
<td>3.7</td>
<td>0.6</td>
</tr>
<tr>
<td>16</td>
<td>Assisted with timetabling subject lessons</td>
<td>71</td>
<td>3.8</td>
<td>0.8</td>
</tr>
<tr>
<td>21</td>
<td>Developed my strategies for subject teaching</td>
<td>76</td>
<td>3.8</td>
<td>0.9</td>
</tr>
<tr>
<td>25</td>
<td>Discussed effective questioning skills</td>
<td>72</td>
<td>3.9</td>
<td>0.8</td>
</tr>
<tr>
<td>36</td>
<td>Provided strategies to solve teaching problems</td>
<td>78</td>
<td>3.8</td>
<td>1.0</td>
</tr>
<tr>
<td>40</td>
<td>Discussed how teaching affected learning</td>
<td>67</td>
<td>3.9</td>
<td>1.2</td>
</tr>
<tr>
<td>42</td>
<td>Gave me new viewpoints on teaching</td>
<td>82</td>
<td>4.2</td>
<td>0.7</td>
</tr>
<tr>
<td>44</td>
<td>Showed me how to assess learners’ outcomes</td>
<td>61</td>
<td>3.6</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>Overall subscale: Pedagogical Knowledge</td>
<td>74</td>
<td>3.9</td>
<td>0.9</td>
</tr>
</tbody>
</table>

This sub-scale shows the largest difference between mentors’ very positive views of their supporting roles and actions as compared to mentees’ perceptions (overall scores for the sub-scale differed by 10%). This is disconcerting, because any model of learning during school placement will expect trainees to, at least, gain pedagogical knowledge. In items with the largest discrepancies (items 7, 14, 40 and 44), it seems the action verbs of statements might have been at the heart of differences. In item 7 for example, discussed my planning for teaching the subject, there might have been different views as to what constituted a proper and supportive ‘discussion’ about lesson planning. Responses to other items about lesson planning do not show such differences. It seems that mentees
might have been satisfied with guidance on the processes and procedural aspects of planning but less happy about discussions as to how effective their plans were in terms of actual teaching strategies and learning activities. This is supported by responses to item 14, assisted with implementing teaching strategies, where there was a very marked difference in perceptions of mentors and mentees (30%). ‘Discussion’ is also the action verb in item 40, about links between teaching and learning outcomes, and here again most mentors thought they provided sufficient support whilst about a third of mentees were not so sure that they did this. Linked with this is, showing mentees how to assess learner outcomes (item 44), where again there was a difference in opinion on the efficacy of support provided. This item was one of only two in the whole survey where the differences between mentor and mentee responses proved to be statistically as well as educationally significant (p=0.03). The discrepancies within this cluster of items seem to resonate with differences found in the first sub-scale, i.e. the noted limited mentee experiences of support through listening and meaningful discussion.

Modelling good teaching practices

Table 4 provides an overview of the views of both groups in the support provided in modelling good teaching practices. This would directly reflect the degree to which the apprenticeship model featured as the model for learning during school placement.

Table 4: Mentees’ and mentors’ perceptions of modelling good teaching practices

| Qu | The supporting teacher: | Mentees | | | | Mentors | | | | | | | | diff |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Showed me examples to plan for subject teaching | 85 | 4.3 | 0.7 | 100 | 4.4 | 0.5 | 0.7 |
| 11 | Modelled subject teaching | 71 | 3.6 | 1.2 | 73 | 3.8 | 0.5 | 0.5 |
| 15 | Displayed enthusiasm for teaching the subject | 89 | 4.0 | 0.7 | 86 | 4.0 | 0.5 | 1.0 |
| 18 | Modelled effective classroom management | 78 | 3.9 | 1.0 | 75 | 3.8 | 0.4 | 0.6 |
| 28 | Showed concrete hands-on materials for teaching | 65 | 3.8 | 1.3 | 90 | 4.1 | 0.6 | 0.2 |
| 31 | Was effective in subject teaching | 78 | 4.1 | 1.1 | 86 | 4.1 | 0.6 | 1.0 |
| 33 | Had a good rapport with the learners | 83 | 4.0 | 1.0 | 77 | 4.0 | 0.7 | 0.9 |
| 34 | Used subject language in line with the curriculum | 76 | 4.0 | 0.7 | 91 | 4.1 | 0.6 | 0.5 |
| 35 | Had well-designed activities for subject learning | 72 | 3.8 | 0.8 | 64 | 3.9 | 0.8 | 0.9 |
| Subscale : Modelling good teaching practices (M) | 77 | 3.9 | 0.9 | 82 | 3.6 | 0.5 |   |

295
There is more variance in mentees’ than mentors’ responses reflected by the overall differences in standard deviations across the sub-scale (0.9 cf 0.5). Differences at personal and school levels are probably important here.

It seems a little odd that about 30% of both mentees and mentors are uncertain that they model subject teaching (item 11). Does this mean that some mentees just do not see their mentors teach? Low scores in mentee responses to item 28, showed concrete hands-on materials for teaching, and item 35, had well-designed activities for subject learning seem to indicate that mentees are seeking practical examples and suggestions for subject teaching that mentors are unable to supply, but sometimes think they are (item 28)! Perhaps their advice is more general and not lesson specific enough to satisfy mentees’ needs.

The curriculum language gap between mentees and mentors (item 34) harks back to the lack of clarity of subject aims and purposes commented on earlier. This discrepancy could also suggest that mentees find it difficult to grasp what teachers mean by terms that have become embedded in their everyday craft knowledge, and that mentees are more familiar with, and expect to communicate in, terminology from curriculum documentation.

Developing reflective practice
The views on the support provided to develop reflective practice are summarised in Table 5 below. This is the most direct indicator of the degree to which both groups see the reflective practice model for learning during school placement.

<table>
<thead>
<tr>
<th>Qu</th>
<th>The supporting teacher:</th>
<th>Mentees</th>
<th>Mentors</th>
<th>diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Assisted reflection on improving subject teaching</td>
<td>86</td>
<td>90</td>
<td>0.1</td>
</tr>
<tr>
<td>19</td>
<td>Discussed my evaluation of subject teaching</td>
<td>89</td>
<td>77</td>
<td>0.7</td>
</tr>
<tr>
<td>20</td>
<td>Observed me teaching the subject</td>
<td>72</td>
<td>90</td>
<td>0.9</td>
</tr>
<tr>
<td>23</td>
<td>Provided oral feedback on my subject teaching</td>
<td>87</td>
<td>77</td>
<td>0.8</td>
</tr>
<tr>
<td>29</td>
<td>Provided written feedback on my subject teaching</td>
<td>72</td>
<td>90</td>
<td>0.1</td>
</tr>
<tr>
<td>38</td>
<td>Reviewed my subject lesson plans with me</td>
<td>88</td>
<td>77</td>
<td>0.4</td>
</tr>
<tr>
<td>45</td>
<td>Clearly articulated what was needed to improve teaching</td>
<td>61</td>
<td>77</td>
<td>0.1</td>
</tr>
</tbody>
</table>
This is the subscale in which there was most often a noticeable discrepancy between mentees’ and mentors’ ratings, although the overall scores do not differ much. There are sizeable differences in the percentages selecting agree or strongly agree options for six of the seven statement items. However, it was not always mentors who were more positive than mentees on facilitating or developing mentees reflective practices. For example for items 19 and 38, discussed my evaluation of subject teaching and reviewed my subject lesson plans with me, mentors seemed more reluctant to agree that such support was provided.

In two cases (items 20 and 29) almost all (90%) of mentors agreed with the statement yet less than three quarters (72%) of the mentees did this. There are clearly different interpretations of what constitutes observation of mentees’ lessons and written feedback on them. These are fundamental and indicate that significant steps need to be taken in the training of mentors so that the expectations of the role are made very clear.

The last item of this category (45), Clearly articulated what was needed to improve, was rated very low by the mentees (61%). In fact this level of agreement was the lowest for all 45 items of the survey. If mentees do not have some way of obtaining oral or written feedback on what steps are needed to improve their teaching, then surely practice becomes merely a set of learned procedures and copied routines. Reflective practice lies at the heart of professional knowledge growth both as a student teacher and, in the reform-based model, as a qualified teacher.

Discussion and conclusion

On the whole, the analysis shows that the groups of mentees and mentors feel very positive about the support provided and received during the mentoring processes, much more so than respondents in previous studies of mentees in Australia (Hudson et al., 2005) and Zimbabwe (Maduvanhu & Zezekwa, 2009). Such differences could hardly be explained by cultural factors where South African mentees may be deferential to authority (i.e. the mentor), since the Zimbabwean study was done in a similar cultural context. Some methodological issues may be related to the very positive results of this study. The sample consisted of volunteers only, and the mentees were all close to graduation and may not have wanted to appear critical just before being awarded their qualifications! It would be interesting to carry out this exercise at different times in the year, for different complete year groups of students. The instrument and analysis methods have the potential for diagnostic feedback helping university-based teacher educators develop relationships between practice schools and their student teachers.

On average, about three quarters of mentees (varying between 61% and 94% of the sample) felt supported by mentors on each of the professional development aspects. The perceived positivity does not differ markedly for the five different subscales. Relatively low agreement with provided support emerged within the subscales for personal characteristics and pedagogical knowledge. Both centred around the mentees’ desire for
support through meaningful discussion of issues, through listening to problems with teaching, rather than a need for being told the solutions to identified problems. The mentors’ perception of support seems more one-directional, and the mentees’ view more interactive.

It is striking that on all subscales a larger proportion of mentors reported that support was provided than the mentees had experienced. The one exception was the development of subject content knowledge, where a distinctly smaller proportion of mentors than mentees reported support. Whereas all mentors claimed providing support in subject content knowledge, many were hesitant about providing help with thinking through the aims of the subject, and the implications of changes in recent curriculum demands for the coverage of classroom teaching and departmental policy. This probably reflects mentors’ uncertainty about curriculum priorities, and lack of training in the implementation of the changing curriculum. This would suggest an opportunity for mentor support, and thus an opening for reform-based teacher education. If mentors consciously play down supporting mentees’ subject content knowledge because they feel they do not have the appropriate clarity or expertise, this may be translated in a need for professional development. Alternatively, the mentors’ reported low level of support may indicate that they do not see this type of support for subject content knowledge as part of their role – they may expect the university to deal with these issues. This speculation about the reasons for limited support in this area illustrates the usefulness of additional data collection through interviews with mentors and mentees.

Comparing the perceived experienced and provided support for the subscales of ‘modelling practice’ and ‘developing reflective practice’, there is no indication that mentees or mentors perceive the support during school placement as prioritising the development of reflective practitioners or exemplary classroom practice. This suggests that there currently is no explicit or implicit preference for any of these traditional teacher education models, providing some feasible implementation space for a reform-based teacher education model.

References


The Reflective Teacher Journal: What does it reveal about teachers’ beliefs and professional growth?

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Abstract

This paper explores how in-service teachers of mathematics in an accredited Advanced Certificate in Education (ACE) programme described their anxieties, concerns and expectations through reflective writing. These are teachers from previously disadvantaged rural schools in the Eastern Cape. Apart from facing various challenges in the schools they taught, they often lack the necessary content knowledge and confidence to teach the subject.

The teachers are expected to keep a reflective journal throughout the contact sessions. They are encouraged to write about both the positive and negative experiences during this time. The journal narratives discussed here are from students on the ACE course.

The different narratives reveal the limited practical knowledge of the teachers and the expectations from the programme to meet their needs. It also serves as a means for obtaining information that will impact on the programme. Teachers are expected to complete a reflective journal on a daily basis responding to questions on their own professional growth. Professional growth is a framework or foundation for professional change. The main purpose of the ACE programme is to support the development of teachers’ mathematical knowledge and teaching skills in an attempt to improve classroom
practice and student achievement. The literature reveals that teachers’ beliefs have strong implications for the way they teach as well as decisions they make with regard to classroom practice. It is therefore important that we are knowledgeable of teacher beliefs and know how to affect them if we intend to improve mathematics instruction. Research indicates that teachers’ beliefs and teachers’ knowledge are related to the instructional decision-making process (Fennema & Franke, 1992; Pajares, 1992; Thompson, 1992). The implications for mathematics teaching are that what a teacher believes about teaching and learning of mathematics, and what a teacher knows about the content, methods, assessment and resources available to teach mathematics influence his or her classroom practices. Most teachers on this course have similar backgrounds and experiences, the exploration of these teachers’ account of their own learning and personal views contributes to better understanding the complexity of teachers’ beliefs, practical knowledge and professional growth. Consistent with Richardson’s (1996) view that attitudes and beliefs are important concepts in understanding teachers’ thought processes, classroom practices, change processes, and learning to teach, I feel it is important in the professional development programme like RUME’s that we not ignore teachers’ beliefs in the reform process.

Introduction

The Rhodes University Mathematics Education Project (RUME) is an independently funded organisation with meaningful links to the University. We offer in-service mathematics professional development programmes to teachers at all grade levels. The programmes are an attempt to assist teachers in deep rural schools to improve the teaching and learning of mathematics. The RUME professional development strategy is built on four distinct programmes, which interrelate with and support each other. These are: The Advanced Certificate in Education (ACE); Collegial Cluster Programme; MathsNet Computer Communication Programme and Focused Intervention Programmes that focus on the development of mathematics teachers in communities of certain selected schools, which have been proposed by a specific funder or stakeholder.

This paper explores how in-service teachers of mathematics in an accredited Advanced Certificate in Education (ACE) programme described their anxieties, concerns and expectations through reflective writing. These are teachers from previously disadvantaged rural schools in the Eastern Cape. Apart from facing various challenges in the schools they taught, they often lack the necessary content knowledge and confidence to teach the subject. The intention of the paper is to share the experiences of in-service teachers of mathematics as they reflect on the mathematics education professional development programme. The main goal of the programme is to educate teachers to become analytical, self-reflective and adaptive agents in the classroom. The challenge of changing mathematics classrooms is characterised in ways recommended in the NCS which require many changes in teachers’ classroom practices. There is no doubt that for the many teachers
working in impoverished schools these changes are a daunting challenge which can cause anxiety.

The RUMEP professional development accredited ACE programme is offered on a part-time basis at the university. It was designed in order to represent a shift from the traditional form of professional development activity consisting of workshops to teach techniques, towards a form involving multiple professional strategies including the use of reflective practice to analyse and improve teaching; and considering teachers as both learners, and researchers in order to build their capacities to understand and improve their own mathematics teaching as well as the students’ abilities.

**Rationale**

As a result of the changes described above, mathematics teachers at all levels throughout the world are being asked to reform their instructional practices, and there has been a universal call for educators involved in professional development support for teachers to revise their approaches to teaching. Lappan (1997) emphasised that there was a need to begin at ground level and build teacher support systems that can educate and assist teachers in changing their own mathematics teaching approach in order to be able to encourage more powerful mathematics and mathematical thinking among their students. She further suggested that new kinds of relationships and conditions are needed for teachers to function and grow as professionals.

In recent years reflection has become a crucial concept in the professional growth of teachers. The focus on reflective practice in the RUMEP programme is an attempt to support teachers to become critical of their teaching and bring about change in their classrooms. It has been reported that reflective practice is an opportunity for meaningful teacher growth (Zeichner & Liston, 1996; Hyatt & Beigy, 1999; Jay & Johnson, 2002).

It has been argued that teacher education reform efforts in the past, with their emphasis on methods, have often been ineffective in improving current teaching practice because they failed to take into account teachers’ existing knowledge, beliefs and attitudes (Kinchin, 2002; Stein, Smith & Silver, 1999). To understand the role of teachers with respect to educational reform, it had been suggested that their beliefs and views be analysed. This is consistent with Richardson’s (1994) view that since beliefs are related to practices, professional development that focuses solely on teaching practices may not be successful in effecting change unless the beliefs and theories underlying the practices are also explored (p.90). It is within this context that this research considers teachers’ beliefs in an attempt to support mathematics teachers in their effort to develop their thinking, reflection, classroom practice and professional growth.

**Theoretical Framework**

Beliefs

In order to provide a framework within which to present a discussion of beliefs in this study, I include some of the definitions and descriptions of beliefs that have been
identified by researchers in this field. Pajares (1992) made use of a wide range of literature in defining teacher beliefs. He quoted Brown & Cooney (1992) who explained that beliefs were dispositions to action and major determinants of behaviour, although the dispositions are time and content specific. Similarly, Harvey (1986) defined belief as individuals’ representations of reality that have enough validity, truth, or credibility to guide thought and behaviour. Further, in his exploration of defining beliefs, Pajares stated that Dewey (1933) described beliefs as crucially important, for they cover all matters about which we have no sure knowledge and are sufficiently confident, to act upon, and also the matters that we accept as certainly true as knowledge, but which nevertheless may be questioned in the future (p. 6).

Aguirre & Speer (1999 cited Ernest, 1989) defined beliefs as personal philosophies (often implicitly held) consisting of conceptions, values and ideologies. According to Lumpe et al. (1998), some researchers say beliefs are considered to be the best of people’s decisions (Bandura, 1986). Irrespective of how beliefs are defined, their importance in teacher education cannot be ignored as they translate into classroom practices (Richardson, 1994, 1996; Thompson, 1992; Ernest, 1986). It is evident from the literature that beliefs drive action and are therefore important in analysing teachers’ classroom practice. Within this context, Nespor (1987) suggested that teachers’ beliefs play a major role in defining teaching tasks and organising the knowledge and information relevant to those tasks. Similarly, Kagan (1992) stated that a teacher’s belief is defined broadly as consisting of tacit, often unconsciously held assumptions about students, classrooms, and academic material taught. Teacher educators involved in reform are reminded of the vital role of teacher beliefs in our courses, research and practices. Oliver & Koballa (1992, cited in Lumpe et al. 1998) indicated that beliefs are oftentimes equated with knowledge, attitudes, or personal convictions or reflect a person’s acceptance or rejection of a proposition (p.124). Tobin, Tippens and Gallard (1994, cited by Lumpe et al. 1998) stated:

> Future research should seek to enhance our understanding of the relationship between teacher beliefs and education reform... teacher beliefs are a critical ingredient in the factors that determine what happens in the classroom (p. 64).

**Teachers Beliefs**

The literature reveals that teachers’ beliefs have strong implications for the way they teach as well as decisions they make with regard to classroom practice. My research is orientated toward Richardson’s (1996) notion that attitudes and beliefs are important concepts in understanding teachers’ thought processes, classroom practices, change processes, and in learning to teach. According to Underhill (1988, cited in Carter & Norwood 1997), it is important that we are knowledgeable of teacher beliefs and know how to affect them if we intend to improve mathematics instruction. It has been shown throughout the literature reviewed that teachers’ beliefs shape the way in which they teach mathematics. For example, Pajares (1992) claims that the beliefs teachers hold influence their perceptions and judgments which, in turn, affect their behaviour in the classroom. He also asserts that understanding the belief structures of teachers and teacher
candidates is essential to improving their professional preparation and teaching practices (p. 307).

Beliefs and professional development
Lumpe, Haney & Czerniak (1998) urge educators to be aware of the importance of teacher beliefs and attend to them in professional development programmes, otherwise reform recommendations will not be successful. Considering the goal of the RUMEP professional programme to challenge teachers’ existing beliefs, views, conceptions and attitudes towards mathematics, I considered that it is important for the educators in the programme to continually try and seek to understand the beliefs of the participants if effective change in their practice is to occur.

In her discussion of teachers’ beliefs, Richardson (1994) explains that since beliefs are related to practices, staff development that focuses solely on teaching practices may not be successful in effecting change unless the teachers’ beliefs and the theories underlying the practices are also explored (p. 90). Haney, Czerniak & Lumpe (1996) agree and indicate that understanding and acknowledging teachers’ beliefs when forming an in-service programme is critical to the success of the programme. I considered that being able to identify and describe teacher’s own perceptions and interpretations of mathematics teaching and learning, would enrich my own understanding of this. The importance of beliefs is central to improving teaching as well as its affects on professional development cannot be ignored.

Reflection
Most of the research on reflection and the quality of reflection warns of the different definitions there are of the concept of reflection. How one interprets the concept of reflection mirrors the aspects that teacher educators and researchers consider to be important in the training of teachers (Mansvelder-Longayroux, Beijaard & Verloop, 2007). However, reflection continually emerges as a suggested way of helping practitioners better understand what they know and do as they develop their knowledge of practice through reconsidering what they learn in practice (Loughran, 2002, p.34). The focus of reflection in RUMEP’s programme is an attempt to support teachers to become critical of their teaching and bring about change in their classrooms. Reflection is defined as systematic enquiry into one’s practice to improve that practice and to deepen one’s own understanding of it (McIntyre, 1993). According to Reiman (1999), when practitioners engage in reflective teaching, they demonstrate a capacity to analyse the process of what they are doing, and to reconstruct their professional and personal schemes, while simultaneously making judgment to adapt their practice so that it best matches the learners’ needs. It is evident then that by reflecting on their practice, teachers could not only improve their teaching, but would deepen their understanding and so enhance their professional growth. The aim of reflection in this programme is to improve practice. Teachers are expected to plan, make provision for learning, teach, reflect and take action. This will ultimately lead to new interpretations of understanding. Freese (1999) drew on the work of Loughran (1995) and Schon (1983) and defined reflection as the process of making sense of one’s experiences deliberately, and actively
examining one’s thoughts and actions to arrive at new ways of understanding oneself as a teacher (p. 898). LaBoskey (1997), cited in Loughran & Russell (1997), described the reflective teacher as one who questions and examines the reasons behind her knowledge, beliefs and practices and their implications, as much and as often as possible (p. 150). Similarly, Zeichner & Liston (1996) suggest that reflective teaching entails a recognition, examination, and rumination over the implications of one’s beliefs, experiences, attitudes, knowledge, and values as well as the opportunities and constraints provided by the social conditions in which the teacher works.

The RUMEP programme provides a variety of experiences, strategies and opportunities to encourage and promote in-service teachers to develop the habit to reflect. Examples include: teaching portfolios; action research (teacher as researcher) and reflective journals.

**Reflective Journals**

The reflective journal is introduced in the first year of the ACE course. The journal is structured in the sense that teachers have to focus on a few questions that guide their reflections. Their responses give feedback to both the teachers and the mathematics educators (lecturers). The purpose of the journal for the ACE teachers is to focus on their own learning on the course, in other words, they document their own professional growth. Reiman (1999) stated that the use of journal writing in promoting reflection is an efficient way to enhance critical reflection. He believes that the development of conscious awareness and reflection through the use of written language drives thinking forward toward conceptual understanding. I also see the journal writing as a means whereby teachers could practice their writing skills as well as express their feelings, concerns and personal beliefs about mathematics teaching and learning. Journal writing is often seen as a popular technique for encouraging teachers to reflect on their professional practice (Bain, Mills, Ballantyne & Packer, 2002).

**Methodology**

Teachers in the ACE programmes attend professional blocks at the university during school holidays.

Throughout the two-year course period the students write reflective journals during the contact sessions to document their professional growth. Teachers complete a daily reflective journal entry. At the beginning of each session teachers are given a structured journal (specific reflective questions) to complete at the end of each day. These questions focus on the teachers’ personal and professional experiences during the contact sessions. These journals are handed in at the end of the contact session.

The current research is ongoing, an attempt to explore the significance teachers give to personal and professional experiences. Consistent with our own views that underpin our professional development model, we strive to transform our own teaching through recognition of teachers’ beliefs and reflective practice.

**Data analysis**
Journal entries were divided into categories according to the five questions that students must respond to. The categories describing the focus of reflection include:

- Positive feelings (Describe satisfaction or pleasure regarding yourself, others, or the class activities).
- Negative feelings (Expressing dissatisfaction or complaints about yourself, others or class activities).
- How did you participate with your group today?
- What do you think you were expected to learn? What did you learn?
- How well do you understand the work? Is there something that you still don’t fully understand?

Discussion

A number of teachers described how they have grown professionally, and evaluated their beliefs against their experiences:

I am so happy about the activities that are being done they have shown me that I have to change from what I was doing in my class and my attitude towards the learners whom I teach.

I feel am a transformed educator. I am more knowledgeable and skilled in maths. I felt confident in applying different strategies, working with patterns and basic knowledge. Also, I have learnt what a good textbook should look like.

I have gained confidence and I am going back to my learners and colleagues and share with them what I have learnt here and put into practice what I am taught here.

I have enjoyed learning about different ways in which learners can find solutions to a problem. It was quite an eye-opener. I cannot wait to implement it in my school situation.

I am now clear about teaching prisms. This is one of the lessons that I struggled to teach in my classroom. Now I am ready to teach it in my classroom.

Teachers indicated how they have grown professionally and it led to new understanding of themselves as teachers and new understanding of classroom practice:

I feel confident now that I can guide learners to discover a line of symmetry in a shape and to differentiate between a diagonal and symmetry.

I learnt more and at last understand how to teach calculus, trig and data handling lessons.

I feel positive because I have learned a lot of new things today. I am amazed at how easy it is to teach some of the components of maths that I was afraid to tackle.
I will now change the way I teach, develop the standard of my teaching and improve my results. Teachers demonstrated a capacity to analyse the process of what they are doing, and to reconstruct their professional and personal schemes, while simultaneously making judgments to adapt their practice so that it best matches the learners’ needs.

By coming to study on this course has made me a better person. The activities that I have done made me see how to teach mathematics so that learners understand it and like it.

The textbooks in my classroom will be of a high standard now that I’ve learnt about book evaluation.

Teachers’ views on language and their own learning during the contact sessions:
If the group discussion is going to be in Xhosa, how will I participate? Group work is there to help each other.
I have a problem with Xhosa communication in groups. I wish something could be done.
I feel alienated because of the language barrier. This does not allow interpersonal relationships to develop...
I am not confident with my language that resulted in my not participating much in class activities that involved talking and explaining to the class.
A colleague and I approached a lecturer about speaking Xhosa when she gets excited while explaining work and she pleasantly acknowledge it.
Pajares (1992) claims that the beliefs teachers hold influence their perceptions and judgments which, in turn, affect their behaviour in the classroom. He also asserts that understanding the belief structures of teachers and teacher candidates is essential to improving their professional preparation and teaching practices (p. 307).

This was especially evident in the following excerpts:
Not understanding activities in problem solving develop an element of hatred towards it.
My weakest point is that I don’t have self-confidence so during activities I will think that my answer would be incorrect...

My feelings are on see-saw. At times I understand what is going on and at times I am totally lost. Will I ever be able to cope? If it is so difficult to me now, how much worse will it get during the course?

My lack of mathematical expression, knowledge and conceptual understanding made me feel uncomfortable.

I found the rules/formula of patterns difficult to understand. Will I ever understand formulae- I must find help very quickly!

My lack of self-esteem made me feel my knowledge is not as good as others’, I became dependent on a group member.
Many teachers pointed to the transformational character of working collaboratively with teachers within the groups during the programme experiences:

I was so happy because we worked together in our group, everybody participated in each activity and we helped each other.
I feel comfortable to share ideas with others in my group I am starting to contribute more than ever. We are learning new approaches to teaching.
Class activities are good because we learn a lot from each other through discussions.

Working cooperatively and sharing ideas motivated me to work with members in my group.

I am happy today because after supper yesterday we met as a group for two hours discussing what we did in the classroom. This made me confident especially when it comes to shapes.

In my group everyone was free to talk with one another. Also, to ask help from each other, raise questions and to disagree when necessary.

Grouping made it possible for me to unleash my potential. Working in a group uplifted my confidence because almost every activity we first discussed as a group then reported to others. This created a lot of personal growth as we shared new ideas and relevant information.

The teachers above reflected that they have gained new insights and improved professional communication by learning to consider and appreciate others’ viewpoints, and these new insights have led to better understanding of mathematics and professional growth.

Green & Smyser (1996) claim that self-reflection is the starting point for professional development. Also, that self-knowledge is essential to self-change. The following teachers acknowledge their lack of knowledge of mathematics by articulating their imperfections or weaknesses:

I have noticed that there is a lot I don’t understand in maths. I needed to be reminded about the many things that I have forgotten. I feel I should work hard in order to understand and know what is going on.

The lack of mathematical expression, knowledge and conceptual understanding made me feel uncomfortable.

I did not know how to measure angles it was such an embarrassment.

I felt frustrated when I could not understand the division strategies. Division is one of the mathematics teaching problems that I have.
Conclusion

In this paper, I have drawn on the reflective writing of teachers to assist us to identify not only the weaknesses of the programme but to find out the needs of the teachers. If beliefs are considered to be the best indicators of a person’s decision making, it is important that a programme like RUMEP' as well as other professional development initiatives do not ignore classroom teachers’ beliefs in the reform process. The RUMEP professional development programme supports the view that unless educators consider the beliefs, attitudes, feelings and experiences of teachers we may not be successful in effecting change.

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Abstract
The purpose of this research was to explore the classroom practices of five early career physical science teachers, working from an understanding of a classroom as a complex system. Narrative descriptions of 28 lessons which I observed form the primary data for this paper. I used a phenomenographic-type approach to explore the variation in classroom activities in these lessons. The validity of classroom observation is threatened by the reactivity of the classroom dynamic to the observer so I asked teachers how they felt my presence had affected themselves and their learners. The activities in the observed lessons could be grouped according to four teaching purposes: firstly introducing learners to new content in the form of general principles; secondly applying the general principles to specific situations by having learners do exercises which then leads to thirdly giving feedback on those exercises; and fourthly revision. In addition three distinctly different patterns of engagement were evident: exposition, question and answer, and conversation. The modus operandi in some classrooms was surprisingly consistent across different contents and grades. This analysis only provides a description of what happens in science classrooms - further research should consider the quality of the content of the lessons and the teachers’ perspectives.

Introduction
For the past eight years I have been involved in the initial preparation of physical science teachers for the South African education system. The problem is that while I work hard preparing science teachers, I have no idea what actually happens in the classrooms of these teachers after they graduate. Nor is my problem unique: South African research on beginning science teachers focuses on students’ ideas at the end of particular courses.
rather than following them into their classrooms (Adler, Pournara, Taylor, Thorne, & Moletsane, 2009). Clark and Linder claim that in South Africa

we have so little understanding of the ‘realities of schooling at the chalk face’ that it hardly seems an exaggeration to propose that we know virtually nothing at all about how individual teachers cope and respond to the challenges of practice, either under existing conditions or when faced with implementing change. (2006, p. 2)

The purpose of this research was to study the classroom practices of five early career physical science teachers, by asking the question: what is the variation in the activities in the classrooms of early career science teachers? This question explores the classroom repertoire of these teachers as they make decisions in negotiating the constraints and opportunities of the educational situations in which they find themselves. In this paper I describe my framework and methodology, then describe my sample and their perceptions of the validity of the classroom observation, before presenting the analysis of the observed lessons.

Framework

A science class can be regarded as a complex system, comprised of individual agents interacting. A complex system has the characteristics of diversity and at the same redundancy (some commonality) amongst the agents. There needs to be decentralized control, which is true of classrooms because learning happens at the level of the individual and cannot be predetermined by the teacher. The structure of a complex system emerges in a bottom-up direction from the interactions of actors within the system, and adapts over time in response to outside influences or perturbations. This emergence and adaptation reflect the learning of the system (Davis, 2004; Davis & Simmt, 2003). Complexity theorists regard theories of learning as nested and appropriate for explaining learning at different levels: Piagetian constructivism (Piaget, 1985) at the level of the individual, social constructivism (Vygotsky, 1978) at the level of the group, and communities of practice (Lave & Wenger, 1991) at the level of the class or school. Complexity science attempts to describe complex systems without addressing meaning, but “is defined more in terms of its objects of study than its modes of investigation.” (Davis, 2004, p. 150).

In attempting to describe the complexity of classroom action, I have framed a research question with two constructs: classroom activities and variation. I have chosen classroom activities as a unit of analysis which is observable within a lesson – the actions and speech of the agents are observable, whereas their thoughts and learning are not. I am interested in the variation in these activities. Phenomenography is a research approach which explores variation in the conceptions which people have of a phenomenon (Marton, 1981; Marton & Booth, 1997). Phenomenographic analysis is similar to grounded analysis (Strauss & Corbin, 1990), allowing the ‘outcome space’ to emerge from the data, and an emergent approach such as this seems consistent with complexity. However in this study, it is not conceptions but classroom activities in which I am interested, although classroom activities reflect a teacher’s conceptions of science teaching (a link I will not explore in this paper). Nonetheless phenomenography has informed my approach insofar as firstly I pooled all the data and did not consider the classrooms of individual teachers separately and secondly I focused on variation.
Methodology

The obvious way to find out what is happening in classrooms is to spend time in them. Thus I spent two days in the classroom of each teacher. However classroom observation is not straightforward. Firstly the very act of introducing an observer into a classroom changes the dynamic of the classroom – in the metaphor of modern physics, the introduction of a measuring instrument changes the quantity being measured. Secondly, the observer is not objective, but comes with subjectivities (Peshkin, 1988) emerging from their own history which affect what the observer notices of what happens - the observer is a particular measuring instrument. There are thus two significant threats to the validity of classroom observation: reactivity - the “influence of the researcher on the setting or individuals studied” (Maxwell, 1996, p. 91) - and observer subjectivity. Integral to my methodology is the way in which I addressed these two threats.

With regard to reactivity, as a teacher myself I know that the presence of a peer in my classroom affects me: I start engaging in metacognition while teaching, in a way that I do not normally do. As I perceive my peer assessing me, I start to assess myself. This has both positive and negative consequences for my teaching: it makes me self-critical which feeds back positively into my teaching, but it also distracts me somewhat from the immediate task of teaching. I anticipated that the teachers I worked with could experience the same effect. To address the reactivity of the research site, I took two steps. The first was to attempt to reduce the effect of my presence on the classroom dynamic (for example I paid attention to issues of power, by positioning both teachers and learners as agents with a choice to help me with my research), and the second was to ask teachers afterward how they felt my presence had affected themselves and their learners. In other words, I took steps to reduce reactivity and to account for it.

With regard to observer subjectivity, I wanted to interrupt my normal practice of classroom observation: as a teacher educator, I have sat in hundreds of lessons, ‘critting’ student teachers. But for this research, I wanted to be able to see science classrooms with new eyes. Instead of judging lessons, I wanted to learn from them. I used the approach developed and used in a local study of teacher take-up of in-service training in mathematics, science and english (Adler & Reed, 2002). This involved writing the ‘story’ of the lesson as it unfolded, and then completing a checklist at the end of the lesson. A focus on description meant that I could suspend judgement, and so I found that this method gave me the ‘new eyes’ I wanted. I also videotaped each lesson, using an unattended video camera in a back corner of the classroom. This enabled me to revisit each lesson, and fill in more details on the lesson narratives. The lesson narratives form the primary data for this paper.

Sample

Table 1 gives details of the teachers who participated in this research. They all qualified as secondary science teachers through a four year teaching qualification in the Wits School of Education, where I was their lecturer for all or most of their science teaching methodology and physics courses. My main reason for choosing my past students is that I want the research to inform my own practice as a teacher educator. These teachers received their own secondary education in diverse schools, and currently teach in diverse schools. I watched at least one lesson in every grade of each teacher. The majority of the
lessons happened to be physics, but I also saw chemistry lessons, and in the junior grades two biology lessons and one earth science lesson. I have not included any ‘repeated’ lessons in this analysis – though no lesson is ever truly repeated.

Table 4: Sample

<table>
<thead>
<tr>
<th></th>
<th>Andy</th>
<th>Bheki</th>
<th>Chrissie</th>
<th>Dumi</th>
<th>Elly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualification:</td>
<td>B Ed</td>
<td>HDE</td>
<td>HDE</td>
<td>HDE</td>
<td>HDE</td>
</tr>
<tr>
<td></td>
<td>B Sc Hons</td>
<td></td>
<td></td>
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<td>6 years</td>
<td>5 years</td>
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<td>experience:</td>
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<td>State</td>
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<td>black</td>
<td>black</td>
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<tr>
<td>demographics:</td>
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<td></td>
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<tr>
<td>Grades taught</td>
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<td>8, 10,</td>
<td>8, 9, 10</td>
<td>10, 11</td>
<td>11, 12</td>
</tr>
<tr>
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<td></td>
<td>11, 12</td>
<td></td>
<td>(+9</td>
<td>(+ 10</td>
</tr>
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<td></td>
<td></td>
<td>Technology)</td>
<td>Maths)</td>
</tr>
<tr>
<td>Typical no. of</td>
<td>33</td>
<td>35</td>
<td>20</td>
<td>20-36</td>
<td>21</td>
</tr>
<tr>
<td>learners</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>present:</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>7</td>
<td>6</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>observed:</td>
<td>(A1,2,4-8)</td>
<td>(B1-7)</td>
<td>(C1-6)</td>
<td>(D1-3,5,6)</td>
<td>(E1-4)</td>
</tr>
</tbody>
</table>

The effect of the observer

As mentioned, I asked teachers how they felt my presence affected themselves and their learners. For practical reasons, this was done for only half of the observed lessons, and four of the teachers. I will first look at how these teachers felt my presence affected their learners, and then how it affected them.

Elly felt that my presence had no effect on the behaviour of her learners. Chrissie’s first impression was that my presence had no effect on the behaviour of a class as a whole, but on reflection she noted that with her grade 10 class,

there were two girls that are usually very on top of everything and would volunteer, and even when I asked the one girl, she gave me some weird answer, it was very out of character for her. So I think it did make a few kids quite shy.
Andy felt that my presence had minimal effect during the three lessons involving practical work, but that in the two of the ‘chalk and talk lessons, learners were “more reserved” and trying to behave better, for example he noted after a grade 8 lesson:

Agh obviously they do notice that somebody’s here, so they always say, "Sir, today we have to be at our best behaviour" (laughs). So they like all behave, you know. So it has an effect in terms of the type of interaction that we have.

Dumi felt that, while learners did not behave differently, they felt privileged to have me visit. I was surprised by this response, but it reflects the rarity of white visitors in township schools. He also noted that my presence had an impact on the language of the classroom – he and his learners “mostly use half Zulu, half English” but a greater than normal portion of the lessons were conducted in English for my benefit. Overall, then, out of 14 lessons, according to their teachers my presence had minimal effect on the learners for 10 lessons, made some more reserved in 3 lessons, and led to better behaviour by some of the learners in 2 lessons.

In contrast there were only two lessons where teachers felt my presence had minimal effect on them. The first was during a prac lesson of Andy’s because “I always have fun at the pracs”. The second was when Elly presented content which she found difficult, during the second day I visited: “today with the content that I was doing, I kind of forgot that you were sitting at the back of my classroom, because I’m struggling to get that message across”. Instead teachers felt at times “maybe intimidated” (Andy) and “more nervous” (Chrissie). Chrissie explained “I’m usually more relaxed. I usually joke around a lot more”. In particular, teachers reported engaging in the kind of metacognition which I anticipated. Elly noted that “now I have to listen to myself”. Similarly Andy reported “usually when I speak I just let go, so for you being here I have to also sort of like think on my thoughts and what I’ve actually said”. In particular, the teachers were concerned about their physics in this on-the-spot reflection. Elly said “And at the back of my head I don’t want anyone to ask me a question that I couldn’t answer.” This is understandable given that I was once their physics lecturer.

In summary, the presence of the observer appeared to have considerably more impact on the teacher than on the learners. This situation was probably influenced by the position of the observer and the video camera at the back of the classroom – mostly out of the learner’s field of vision, but in the teacher’s.

Analysis

From analysis of the lesson narratives, it emerged that the activities in the observed lessons could be grouped according to four teaching purposes: firstly introducing learners to new content in the form of general principles; secondly applying the general principles to specific situations by having learners do exercises which then leads to thirdly giving feedback on those exercises; and fourthly revision. Under the banner of revision, any of the first three activities could be enacted: re-teaching, exercises and marking of those exercises. These activities often form a teaching sequence:

Introduction of general principles → application → feedback (→ revision)

This teaching sequence can be enacted in a single lesson or over a series of lessons. The first two of these activities resonate with two of the teaching purposes identified by
Mortimer and Scott (2003) in their analysis of talk in science classrooms. But Mortimer and Scott do not consider the need for closure on tasks given to learners. Achieving closure through feedback can be boring, as Chrissie illustrated: “I hate marking, it’s my worst”.

In the first activity, introduction of general principles, three distinctly different patterns of engagement were evident. These patterns used the possible sources of information (teacher, learners and texts) in different ways. The first is exposition which involves a delivery of information. On some occasions the source of information was the teacher, who spoke without notes, and got learners to record the information either by dictating or writing. Alternatively a text (a handout or a workbook) was used as the primary source of information, with either the teacher or a nominated learner reading aloud. The learners filled in gaps or annotated the notes in some way under the teacher’s instruction (e.g. “highlight that word”).

Question and Answer or Q&A was the second pattern of engagement which emerged. Here learners answered a series of questions, either drawing on their own knowledge or information given in a text. For example, Dumi previously gave his grade 11s a handout on torque, and then in the lesson asked a series of questions. His learners sought answers in the text, and he then summarised the main points on the chalkboard. Bheki gave his grade 8 learners a handout with questions on the solar system, and access to a variety of books.

The third pattern of engagement was that of conversation. Although interactive like the Q&A pattern, in a conversation all parties ask questions and can influence the direction whereas in Q&A the teacher asks the questions along a predirected route and the learners answer. In Q&A, the teacher judges the correctness of answers, whereas in conversations, learners judge each other, often because the teacher deliberately suspends judgement. In Q&A, the learners mostly interact with the teacher, whereas in a conversation, the learners interact with each other, turning to look at each other, and responding to each other without the teacher interjecting, although the teacher often chairs the taking of turns. The teacher promotes this interaction by redirecting learner questions to the whole class. This notion of conversations within classrooms is popular with complexity theorists (Davis, Sumara, & Luce-Kapler, 2000; Davis & Sumara, 1997).

The conversations arose in different ways with different teachers. Bheki deliberately set up some of his lessons as conversations. For example he got his grade eights to discuss whether to build a nuclear power station. They had no prior knowledge of nuclear power, and so were required to use the textbooks and other books available in the classroom to find information. In Chrissie’s lessons, the conversations arose spontaneously during lessons. In contrast Dumi typically set aside time at the end of a lesson in which he invited questions. His learners anticipated this, and so always had thoughtful questions prepared, such as “Where does the salt in the sea come from?” after a lesson on the hydrosphere, and “Is it possible to relate the principle of moment and the principle of the law of momentum?” after a lesson on torque. A distinctive element of the conversations was that learners brought information which surprised their teachers, for example Chrissie’s grade eights explained density in terms of how tightly particles are packed, even though she had not used a particle model in talking about density. Complexity
theorists refer to this approach as occasioning – allowing things to “fall together” in complex and unexpected ways.” (Davis, et al., 2000, p. 144).

Questions were also asked by learners in other forms of engagement – in fact learners freely asked questions with all the teachers. However the nature of the questions was different. Questions asked in exposition lessons tended to be concerned with the accuracy of the notes which learners recorded. For example, in a lesson in which Andy drew a diagram of hydrolysis and talked about the structure of the atom, the sequence of questions asked by learners was: “Is it ‘a node’ or ‘anode’? Is that a heading? Sir, are we writing that down? Sir, doesn’t protons have a formula? Sir, what is the mass measured in? What’s the heading?” This series of questions suggests that the teaching purposes of the teacher should not be confused with the purposes as perceived by learners, for example: to take notes. It also illustrates how learners contribute to the emergent action in the classroom both by the questions they ask, and the questions they don’t ask.

These three modes of engagement correlate with the ‘communicative approaches’ identified by Mortimer and Scott. They classified classroom talk as interactive or non-interactive, as well as dialogic or authoritative. In a dialogic approach, “attention is paid to more than one point of view” (2003, p. 33) whereas in an authoritative approach only the voice of science is admitted. These two axes lead to four possibilities, as shown in Table 5. I show where the patterns of engagement which I observed fit into this table.

Table 5: Mortimer and Scott’s four classes of Communicative Approaches

<table>
<thead>
<tr>
<th>Interactive</th>
<th>Non-interactive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dialogic</td>
<td>Conversation</td>
</tr>
<tr>
<td>Authoritative</td>
<td>Q&amp;A</td>
</tr>
<tr>
<td>Exposition</td>
<td></td>
</tr>
</tbody>
</table>

These three modes of engagement were also evident in the other classroom activities. For example, feedback on tasks which the learners had done could be achieved by the teacher reading out the answers (exposition), by the teacher reading the questions and getting learners to answer, either orally or on the chalkboard (Q&A), or by a conversation in which learners argued with each other about a solution, with the teacher delaying judgement. I have represented all the types of activity and the modes of engagement in Table 3 and shown which lessons drew on which activities and modes of engagement. I have indicated lessons involving practical work with asterisks. The distribution of asterisks indicates that practical work can be used for different teaching purposes and in different patterns of engagement.

Discussion

Table 3 overleaf summarises the answer to my research question about the variation in the activities in the classrooms of early career science teachers. Consistent with a phenomenographic approach, I have pooled my data, so the table gives the breadth of the repertoire across all classrooms in the 28 lessons I observed. However it is interesting to note that, on the two days observed, the modus operandi in the classrooms of the three male teachers was surprisingly consistent across different contents and grades. In
contrast, there was a wider repertoire in the classrooms of the two female teachers, and in
the case of Chrissie, within a single lesson. However the sample is too small for the
gendered aspect of this conclusion to have weight!

This analysis has simply provided a description of what happens in science classrooms. I
have not passed judgment on the quality of the lessons, though the reader may do so
based on the descriptions given. But central to the quality of lessons is the quality of the
content constituted in lessons, i.e. the quality of the science made available to learners on
the plane of the classroom. The quality of a lesson cannot be judged without close
attention to this aspect – a dialogic, interactive lesson which uses apparatus is not a
productive lesson if the content constituted is weak. So a further step in this research will
be to examine the content of the lessons. The analysis has also not made space for the
teachers’ voices beyond questions relating to the validity of the observed lessons. So their
rationales for particular approaches and the conceptions of science teaching which inform
their repertoires are another area worthy of study. In addition, in order for this research to
speak back to teacher education, it would be interesting to know what these teachers see
as having influenced the ways in which they occasion learning in their classrooms.

Table 6: Outcome Space: classroom activities (* denotes lessons involving practical
work)

<table>
<thead>
<tr>
<th>Activity: Pattern of engagement:</th>
<th>Introduction of general principles</th>
<th>Application</th>
<th>Feedback</th>
<th>Revision</th>
</tr>
</thead>
</table>
| Exposition                      | Source of knowledge: T
T talks and dictates / writes from head (A1, A5, A7*, A8)
OR:
Source: text
T/ L reads text and T elaborates. Ls listen and possibly annotate text or fill in gaps.
(A6, A8, C1, C4) |
|                                 | T works through example on board (A8) | T reads answers and Ls mark their work (A5, A6, C1, E2, E4) | T re-teaches (A4) |
### Q&A

(whole class / groups / individual)

<table>
<thead>
<tr>
<th>Source: text / Ls</th>
<th>Ls answer questions in text in groups or individually.</th>
<th>T gets Ls to answer questions (either by reading their answers or writing on the board)</th>
<th>Ls answer straightforward questions.</th>
<th>T responds to L queries (C1, C5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T asks questions, and marks significant answers by writing on board (B2, D1, D3, D5, E3)</td>
<td>T responds to L queries (A6, A7*, C1, C3*, C6*, E2)</td>
<td>(A6, C1, C4, C5)</td>
<td>(C1, C5)</td>
<td></td>
</tr>
</tbody>
</table>

### Conversation

(whole class / groups)

<table>
<thead>
<tr>
<th>Source: texts, T and/or Ls. Whole class discussion (B1*, B4, C1, C4, C6, D1, D3)</th>
<th>Ls work on a demanding problem in small groups (A2*, B5, B7, D2, E1, E4)</th>
<th>Ls take turns at board, building on and debating a solution. (B5, B7, E1, E4)</th>
<th>Ls work on a demanding problem in small groups (B3, B6)</th>
</tr>
</thead>
</table>

### References


Acknowledgements
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The use of Analogies in Chemistry Teaching in Mozambique

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Abstract
This article is part of a research carried out for a Masters Degree in Science Education. The central topic of the research is the use of analogies at secondary schools in Manica province in Mozambique. In the last three decades the use of analogies and metaphors in the learning process has been topic of many studies. For instance, Cachapuz (1989), Duit (1991), Treagust et al (1992) and Daught (1995), have demonstrated that the use of analogies plays an important role in the process of teaching and learning chemistry. Bachelard (1996) states that if analogies and metaphors are not correctly used the learning process may fail to achieve its aims. Most of the contents introduced in Chemistry at secondary schools are full of analogies, but many teachers repeat them without any critical reflection in order to find those which are based on students’ context. The general aim of the research is to emphasize the importance of using analogies and metaphors in Chemistry subject in secondary school in Manica, a central province in Mozambique.

Introduction
In the last three decades, the use of analogies and metaphors in the teaching and learning process were widely studied. Authors like Cachapuz (1989), Duit (1991) and Daught (1995) demonstrated that the analogical thinking is important for the simulation of the
science contents. In this aspect, the use of analogies can improve and develop the cognitive perspective and facilitates the heuristic procedures. Therefore, Bachelard (1996), says that analogies and metaphors, if not correctly used may hinder the knowledge acquisition of the science.

A problem may rise if teachers use analogies without any critical reflection in order to find analogies based on the context of the students. There is a tendency to get analogies from the text books that are always out of the student’s context. For example, Monteiro & Justi, (2000) during their study observed that the use of pudding as analogy to explain the atom concept according to Thompson could drive students to imagine atom as a real pudding. Some students draw atom based on this analogy as shown below:

![A picture of an atom based on pudding analogy.](image)

**Figure 1.** A picture of an atom based on pudding analogy.

**Research question**

The study was guided by the general research question: What are the analogies used at the rural and urban schools in districts of Manica, Sussundenga and Chimoio?

**Rationale**

The use of analogies is frequent in teaching chemistry and in other subjects. If teachers are not aware of the types of analogies to use, they might use analogies which are not familiar to their students and if so, analogies will rather act as a barrier instead of facilitate the learning process.

**Relevance of the study**

The relevance of this research can be viewed from two perspectives. First, for the researcher the study can be viewed as an opportunity for professional development. By engaging in reflecting about the analogies in use by teachers and in textbooks at the selected schools the researcher critically reflected on his own practice as a chemistry teacher educator. Secondly for the teachers who participated in the study, the research contributed to raise their awareness about the use of analogies. It is further expected that other readers may also gain some inputs in reference to their practice in similar or different contexts.

**The Research Methodology**

The research was qualitative using a naturalistic and ethnographic approach. Interviews and observations were used as techniques to generate data. The interviews were unstructured. The questions were open and there was no limitation for the subjects to answer. These interviews are frequently used to investigate a problems
or situations not well known. The interviews were conducted in order to collect information about the type of analogies teachers use in their classes, as well as, the motivation they have to use them. The sampling strategy chosen was non-probabilistic purposive. Teachers with a minimum of bachelor degree and with more than five years experience in teaching were chosen. Complementary data was collected by analyzing the textbooks in use in those schools.

Quality standards

Guba and Lincoln (cited in Afonso, 2007) refer to alternative standards for conventional evaluation. They mention three approaches, namely, the parallel or quasi foundational criteria, the hermeneutic process and the authenticity criteria. We based on the parallel criteria where attempts are made to find correspondences with the traditional criteria for evaluation. Internal validity is replaced by credibility, external validity or generalizability is replaced by transferability, reliability by dependability and objectivity by confirmability.

Credibility and transferability were defined as the standards to judge the quality of the research. Credibility asks for the degree interpretation are in concordance with the perspective of the participants. Transferability for this research asks about the impact it may have on other science teachers in the same context or in a different context (Afonso, 2002).

Data example

Question: What do you think about the importance of using analogies in chemistry?
Bemasi: Analogies are very important and fundamental to motivate students. There are however some disadvantages in using analogies as the student may misinterpret what is said.
Botha: Analogies are important because they help students understand the content and link with everyday life.

Question: What kind of analogy do you use for atom according to Thompson?
Jefra: I use a cake or a soccer ball. I tell them that the soccer ball has some black and white parts irregularly distributed. This is the same as in the atom of Thompson; the particles are not regularly distributed.

Bemasi: I use the analogy of a cake made with raisin
Asse: I use as analogy apples.

Question: Which analogy do you use for the concept ‘valence’?
Jefra: I say that to form compounds there are specific elements (…)
Botha: I speak about arms. I say that if they shake hands using one or two hands. If they use one hand the valence is one, if they use two hands to shake one hand the valence is two.

We present in the following paragraphs data from one teacher. The data presented above focused in three questions and gives a general overview of their responses. We will present now only one teacher to allow a different perspective and deeper understanding of the use of analogies.

Question: Which analogy to you use for equilibrium?
Asse: I use the analogy of a big track with golf balls inside.

Question: Do students know about golf?
Asse: Probably the majority not.

Question: How do you explain, using that analogy?
Asse: I say that if a track is full of those little balls. When the track moves the balls moves too … but I understand it is difficult to understand… but other analogies do not work too. For example the analogy of fishes in an aquarium or a pendulum... they do not show that concentration remains the same. I also read on the internet the use of a mat.

Data interpretation

In general teachers showed some difficulties in explaining analogies they use. During the interviews it also came out that most teachers had never thought about the use of analogy. In spite of that they all recognized that analogies are very important in teaching and learning chemistry. We think that more than our interpretation the data collected is relevant in the context of reflective practice. We found that after the interviews teachers were more aware about the use of analogies and became more critical thinkers about the analogies they were using.

Findings

The findings showed that most of the teachers use analogies in their lessons, without taking into account the context of the students. They normally use the analogies out of context of their students. Analogies of pudding for atoms for example, showed to be one mostly used even in rural areas where it was likely that students have never saw a real pudding. The study also revealed that the textbooks in use at secondary schools, present some analogies although most of them do not reflect the reality in Mozambique.

One of the recommendations from the study is that analogies should be included as topic to be studied on the context of didactic of chemistry classes at Universidade Pedagogica.

Reference list


education, Curtin University of Technology, Perth.

Acknowledgements
We would like to thank the teachers interviewed. Without their willingness to participate this research would not have been possible.

Effects of Dialogical Argumentation Instruction (DAI) in a Computer-Assisted Learning (CAL) environment on grade 10 learners’ understanding of concepts of chemical equations

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Many learners struggle to learn physical science concepts (Nakhleh, 1992). The conflict between science conceptual understanding of a science term or phenomena and the commonly accepted scientific meaning of a term may result in science misconceptions. In an attempt to cover the content laden science curriculum, teachers tend to hastily cover important theoretical concepts of a unit, without rigorous conceptualisation of scientific terminology. The majority of schools in the Western Cape have Information Communication Technology (ICT) resources, but they do not know how to use it or to
use it optimally (Department of Education, 2009). The problem is compounded by the fact that many schools do not have well equipped and functional science laboratories for individual and group practical work nor resourced libraries to access science related research material.

This study is directed at determining whether Dialogical Argumentation Instruction (DAI) when used in a Computer-Assisted Learning (CAL) classroom environment, may enhance grade ten learners’ understanding of chemical equation concepts. Furthermore the study will seek to answer the following questions:

1. What is the status of Computer-Assisted Learning (CAL) in selected schools in the Western Cape?
2. Do grade 10 learners exposed to Dialogical Argumentation Instruction (DAI) demonstrate a better understanding of chemical equation concepts, than those not so exposed within a Computer Assisted Learning environment?
3. Are the learners’ concepts of chemical equations related to their age, sex or socio-economic background?

This research is located within the interpretive paradigm and will include both a quantitative and a qualitative approach. The qualitative approach will include a survey, in which information will be gathered from the education department and the selected schools to explore the status of CAL at the selected schools. It will also include an ethnographic study to describe and understand the learners and their classroom environment by means of interviews and observation of class sessions. The quantitative method will entail a quasi-experimental design to measure the differences between the experimental and control groups. The following format will be used for the quantitative design:

\[ O_1 \times O_2 \quad (E) \]
\[ \quad \ldots \ldots \quad O_3 \quad O_4 \quad (C) \]

\( O_1 \) (pre-test) and \( O_2 \) (post-test) will be the experimental group (E) that will be subjected to an intervention, \( x \), which is the Dialogical Argumentation Instruction. \( O_3 \) (pre-test) and \( O_4 \) (post-test) is the control group (C) which will not be subjected to Dialogical Argumentation Instruction. However, both groups will be exposed to the use of Computer Assisted Learning.

Data will be collected using structured questions, semi-structured interviews, a classroom observation schedule and a Science Achievement Test (SAT).

The sample will consist of five randomly selected high schools in District North (circuit 3) of the Western Cape Education Department. The collected data will be used to determine the status of CAL in the selected schools, interviews will be coded and the results of the SAT will be used to determine cognitive achievement in the experimental and the control groups.

Permission, confidentiality and anonymity of the respondents will be maintained at all times and only the general findings will be made available in the final report of this research.

Since respondents are at the same school and in the same grade, I will have to find ways to address possible contamination of data. Another challenge is the Hawthorn Effect, to ensure that the findings are the result of the intervention and not something else. The
significance of this study is to assess whether Dialogical Argumentation Instruction has the potential to revitalise science education and to contribute to the pedagogy of science teaching. It is hoped that the findings of this study will help to identify procedures of implementation of CAL in the selected schools as well as to suggest ways in which the problems can be ameliorated. It is also hoped that the findings would provide useful information about the effectiveness of using a DAI in teaching science concepts.

BACKGROUND

The National Education Department’s e-Education policy states that learners should be Information Communication Technology (ICT) literate by the year 2013 and that new models of learning should also be created to improve curriculum delivery in schools (DoE, 2003).

Most curriculum material are electronically available and is provided by education departments and service providers. Although computers can play a positive role in the teaching-learning process, it must be used within a conducive pedagogical environment.

Dialogical Argumentation Instruction (DAI) could provide the necessary atmosphere within which learners can acquire new learning and communication skills, correct erroneous concepts and broaden their worldview.

This research project will explore how Dialogical Argumentation Instruction (DAI) within a Computer-Assisted Learning (CAL) environment will enhance learners’ understanding of concepts of chemical equations. In particular the research will focus on aspects of dialogical argumentation and whether it is applicable to the science classroom. This study will also investigate whether to modify, adopt or redesign existing argumentation theories to improve the learning of concepts of chemical equations. Computer Assisted Learning (CAL) will be used to provide the base on which to build an appropriate argumentation framework.

Since the introduction of computers into education, more than twenty years ago, education authorities globally have believed that it would drastically improve learner performance and achievements. However, many studies have shown that the use of computers in education has not improved learner performance and achievement significantly (Koshmann, 1996).

However, computers do have an important role to play within the educational set-up, especially when it is used together with instructional strategies. According to Bliss and Osborn (1989) these tools, together with well-designed CAL programs can enhance both the practical and theoretical aspects of science teaching and learning at schools. They state further that:

The advantages of CAL in science lessons is that it can link school science with contemporary science, providing immediate feedback, help with conceptualising of abstract concepts and minimises laborious manual processes and give more time for thinking, discussion and interpretation.
ICT must be used within a conducive pedagogical environment for effective learning to take place (Taylor, 2007). This study will attempt to show that Dialogical Argumentation Instruction could provide such a pedagogical environment. It will also highlight the important role of the teacher and the computer as mediators in the learning process and also as co-constructors of knowledge (Vygotsky, 1979).

Another aspect of this study is to determine to what extent CAL in science teaching and learning is being used currently in selected schools in the Western Cape. A number of schools in the Western Cape have ICT resources. For example, School A in Kraaifontein have data projectors in every classroom. My observation has been that these are not used optimally. This research will also explore the role that an organisation like TRAC, at the University of Stellenbosch, plays in using computer technology and specifically developed curriculum material to show learners how science and mathematics are used to solve real world problems. Khanya is also an IT service provider of the Education Department, which helps the DoE to equip all schools with computers and IT training. Another initiative by Dimension Data, a Non-Governmental Organisation, is the Video In Knowledge Out (VIKO) project, which mainly present learning material by means of video presentations.

RATIONALE

The current information explosion that is being experienced globally and the South African outcome-based curriculum (OBE) which has been reviewed recently and called the Curriculum Assessment Policy Statements (CAPS) encourage teachers to use various instructional strategies (DoE, 2003). Teachers have to tap into learners’ interests and hobbies like, cell phone, television, computer games, computers, etc. to create a learning environment which is engaging, interesting and augments expository instruction.

The dominant traditional form of instruction, talk-and-chalk, does not address the challenges of the new curriculum aims effectively. We are living in an information age where learners are confronted daily with the electronic media and the use of computer technology with design and imaging capabilities. Use of these technologies may form part of the teaching and learning environment.

PURPOSE OF STUDY

This study will attempt to determine whether Dialogical Argumentation Instruction (DAI) can enhance grade ten learners’ understanding of concepts of chemical equations within a Computer-Assisted Learning (CAL) classroom environment.

RESEARCH QUESTIONS

This study will seek to answer the following questions:
1. What is the status of Computer-Assisted Learning (CAL) in selected schools in the Western Cape?

2. Do grade 10 learners exposed to Dialogical Argumentation Instruction (DAI) demonstrate a better understanding of chemical equation concepts through a Computer Assisted Learning environment, than those not so exposed?

3. Are the learners’ concepts of chemical equations related to their age, sex or socio-economic background?

LITERATURE REVIEW

Construction of knowledge

Many learners at all levels of high school struggle to learn physical science concepts, but are often unsuccessful (Nakhleh, 1992). A great number of studies have been conducted to discover the reason why learners experience difficulties in understanding some scientific concepts. Learners generate their own meaning of concepts based on their background, attitude and experiences. The learner’s preconceptions determine which information they will pay attention to. When learners learn, they formulate and make sense of information around them from their own point of view. These concepts come from two sources namely, scientific knowledge and informal knowledge (Mpofu, 2006).

Nakhleh (1992) regards learning as a cyclical process. First the new information is compared to prior knowledge, and then it is fed back into that same knowledge base. Learners selectively attend to new information presented and their preconceptions determine which information to assimilate. The brain actively interprets this selected information and draws inferences based on its stored information. The newly generated meanings are then actively linked to the learner’s prior knowledge base.

These coherent understanding of events and phenomena are cognitive structures. They are composed of interrelated concepts. Each concept is formed by a linked set of simple, declarative statements called propositions that represent the body of knowledge the learner possesses about a concept. For example, “An atom contains a nucleus”, is a proposition that contains a declarative statement. Concepts, therefore, are considered to be the set of propositions that a person uses to infer meaning for a particular topic.

When there is a difference between the conceptional understanding of a learner and the commonly accepted scientific meaning of a term, there is interference in the learning process. These interferences are called many names like, misconceptions, preconceptions, alternative frameworks, children’s science, and learners’ descriptive and explanatory systems. Creating a cognitive structure of complex body of knowledge in science and chemistry in particular, is not easy, that is why learners find it difficult to do science” (Nakhleh, 1992).

Collaborative learning

Studies of Crook and Kumpulainen (1994), all emphasize the important role played by
peer interactions in the development and negotiation of shared meaning and understanding. They identified three cognitive benefits: articulation, conflict and co-construction. They also content that learners in collaboration have to articulate and public their ideas and this help them clarify their concepts. To resolve conflict when disagreement arises, learners have to justify and defend their positions and this forces them to reflect on and review their understandings. When working jointly on a task, learners can complete and build on each other’s ideas and incrementally co-construct shared understanding. Conflict is based on the Piagetian-perspective of learning, when disequilibria between new information and existing knowledge result in cognitive development and co-construction of knowledge is based on the Vygotskian-perspective, where mediation help to assist the learning process.

Mercer and Wegerif (1999) contend that talk between learners is valuable for construction of knowledge. He identifies three types of talk from collaborative interactions: disputational talk - which is characterised by disagreement, and individual decision-making, cumulative talk – which is positive but uncritical decision-making, and explorative talk – which is constructive and critical engagement involving argumentation and hypothesis testing.

Drawing from their studies Mercer and Wegerif (1999) claim that exploratory talk is productive talk as it is talk in which ideas are explicitly debated, request for ideas and justifications for challenges are made, and alternative suggestions are offered. They emphasised that the quality of learners’ interactions is critical to the learning outcome.

**Computer-Assisted Learning (CAL)**

When looking at learning at the computer, we find that CAL programs offer mostly individual learning, but however these programs can also be used in a collaborative context. Light and Littleton (1999) content that learners interacting around a computer is a productive way of learning, arguing that the ensuing peer interaction facilitate individual learning as well as the joint construction of understanding.

Crooke and Kumpulainen (1994) suggest that the benefits of classroom computer use arise from the fact that computers lend themselves very well to the collaborative mode of use. Mercer and Wegerif (1999) suggest that while traditional teaching can often be very teacher-centred, the computer does not have the same social role and authority as an teacher and so learners are much less inhibitive in their discussions by its presence.

If CAL programs are well designed and incorporating multimedia features, it can offer unique learning experiences to learners that other media cannot provide. Simulations, as one form of CAL programs allows learner to freely experience, explore and manipulate the microworld by changing parameters and variables and visualising immediately the consequences of their actions (Bliss and Osborn, 1989). Using these programs learners can formulate and test their hypotheses and reconcile any discrepancy between their ideas and the observation in the microworld (Tao and Gunstone, 1999). De Jong and van Joolingen (1998) also contend that simulations are well-suited for discovering learning, a form of learning that involves hypothesis generation and testing that leads to knowledge.
construction. Video clips, another form of CAL programs, are also conducive to aiding learners’ knowledge construction. They show physics phenomena and processes with multimedia (moving pictures, narration and text) that can help learners develop understanding in ways that are superior to forms that use one media, e.g. text alone. Very important is that they provide focal points for discussion and reflections if learners are directed to the relevant key questions or issues of a topic. These CAL programs can be used as a mediator for knowledge construction.

THEORETICAL FRAMEWORK

Socio-cultural constructivism

It is incumbent upon the teacher to create an environment which encourages learning. The teacher should use teaching methods that will make the lessons interesting and encourages learners’ creative and critical thinking.

This study is also underpinned by socio-cultural theory as espoused by Piaget and Vygotsky. In these scholars’ viewpoint learning takes place when the learner incorporates new experiences into existing mental structures and reorganises those structures to deal with more complex problem experiences. In other words, knowledge is constructed as one makes sense of the world around him/her. By interacting with one’s environment experiences are gained which are then used to relate to that environment in a sensible and responsible manner. It is in this regard that a learner takes responsibility for his/her learning.

However, this sort of learning environment is not likely to occur if the teacher dominates the instruction process through the talk-and-chalk teaching method. Learning is a cultural activity, which enables one to relate in a meaningful way to the human and material environment. Within the socio-cultural constructivist regime arguments and dialogues are an effective way of communication and freedom of expression.

Argumentation

Argumentation and dialogue can be used as effective tools in enhancing teachers’ and learners’ conceptual understanding as well as increasing their awareness of the tentative discursive Nature Of Science (NOS) practices.

Toulmin’s Argumentation Pattern (TAP)

Toulmin’s Argumentation Pattern (TAP) is such a theory which is based on deductive-inductive discourses and has been used by many science teachers to enhance teachers’ and learners’ understanding of the NOS (Erduran, Simon & Osborn, 2004). TAP essentially involves the following aspects, processing of data – which is the facts or evidence used for supporting a claim, claims – which is the statement or belief about a phenomenon whose merits are in question, warrants – which is statements used to establish or justify the relationship between the data and the claim, backings – which is the explicit assumptions underpinning the claim, qualifiers – which is the conditions
governing the claim, and rebuttals – which is statements that show the claim is invalid (Toulmin, 1958). TAP argumentations in the classroom discourse was classified into seven levels of argumentation by research learners at UWC (Ogunniyi, 2007a), from level 0, which is a non-oppositional argument to level 6, which involves arguments with multiple rebuttals challenging the claim and / or grounds. This coding mechanism will useful in analysing learners’ thinking patterns.

Contiguity Argumentation Theory (CAT)

Contiguity Argumentation Theory (CAT) dates back to the Platonic and Aristotelian era. The Contiguity Theory is a learning theory which states that more than one distinct thought system can co-exist to create an optimum cognitive state. The CAT recognizes five categories into which conceptions can move within a learner’s mind or amongst learners involved in dialogues justifying scientific and / or IKS-based conceptions (Ogunniyi, 2007a). These five categories exist in a dynamic state of flux in a person’s mind, namely the dominant mental state – when it is the most adaptable to a given context e.g. living in a community where people strongly belief in witchcraft, the suppressed mental state – when the dominant cognitive stage is overpowered by another more adaptable mental stage e.g. a religious persons that become enlighten by scientific facts, the assimilated mental state – when the dominant mental stage is absorbed into another more adaptable mental stage e.g. a black person taking on customs of a white culture, the emergent cognitive stage – when an individual has no previous knowledge of a given phenomenon as would be the case with scientific concepts and theories e.g. atoms, gene, entropy, theory of relativity, etc., and an equipollent mental state – when two competing ideas or worldviews tend to co-exist in the mind of the individual, without necessarily resulting in a conflict e.g. creation and evolution.

This theory will help to establish the learners’ dominant or adaptable metal state in terms of everyday knowledge, misconceptions and scientific knowledge.

METHODOLOGY

This research is located within the interpretive paradigm, therefore it will try to interpret and give meaning to the actions and responses of the learning experience of learners. This approach will give a thick description and help to make sense of the learning environment.

DESIGN STRATEGY

This research will include both a quantitative and a qualitative approach. The qualitative approach will include a survey, in which information will be gathered from the education department and the selected schools to explore the status of CAL at the selected schools. An ethnographic study will also be conducted to describe and understand the learners and their classroom environment by means of interviews and observation of class sessions.

The quantitative method will entail a quasi-experimental design to measure the differences between the experimental and control group. The following format will be

\[ O_1 \times O_2 \quad (E) \]

\[ O_3 \quad O_4 \quad (C) \]
used for the quantitative design:

$O_1$ (pre-test) and $O_2$ (post-test) will be the experimental group (E) that will be subjected to an intervention, $x$, which is the Dialogical Argumentation Instruction. $O_3$ (pre-test) and $O_4$ (post-test) is the control group (C) which will not be subjected to Dialogical Argumentation Instruction. However, both groups will be subjected to the use of Computer Assisted Learning.

The independent variable of this research will be the different methodology strategies that will be used and evaluated, namely DAI and Traditional Instruction. The dependent variable will be the performance of the learners within the different pedagogical settings and their achievement at the end of these sessions. In order to ensure that the results of this research are reliable, the degree of difficulty of the content of the sessions must be the same in both cases by means of CAL and the same teacher must conduct the sessions.

Finally data will be analysed scientifically to find the trends, patterns and to draw clear conclusions in order to ascertain, whether DAI do enhance the understanding of the grade ten learners.

INSTRUMENTS

Questionnaires with structured questions will be used to conduct a survey to determine the status of CAL at the selected school. Example:

1.1 Which of the following Information Communication Technology (ICT) tools is in the science classes / laboratories and how much?
   a) Overhead Projector(s):
   b) Computer(s):
   c) Data Projector(s):
   d) Interactive White Board:
   e) Television:
   f) VCR / CD player:

Semi-structured interviews and a classroom observation schedule will be used to conduct an ethnographic case study to address research question three, to learn from the learners’ experiences and their personal voices. Example:

1. Did you understand the work that was covered in the last three sessions?
2. Which aspect of the sessions did you find most helpful?
3. Explain your answer to no. 2 above.
4. Do your other subject teachers also use the same teaching method?
5. Do you think that the teaching method used in the sessions could be helpful in your
other subject? Explain.

A Science Achievement Test (SAT) will be used to determine the conceptual understanding of the learners about chemical equations concepts before and after the study. Example:

1.1 For each of the following phenomena listed, indicate the nature of the reaction by writing: A: acid-base; B: redox; C: precipitation; D: dissociation.
1.2 Write a balanced equations for each reaction.

(a) Hydrochloric acid solution in sodium chloride. _____
(b) Zinc blade put in hydrochloric acid solution _____
(c) Formation of rust on iron blade _____
(d) Petroleum burning _____
(e) Metal corrosion _____
(f) The colour change of a cut apple _____
(g) A nail in water bleach _____
(h) Sodium chloride in water _____
(i) A rubbed ebonite stick _____
(j) Cleaning of brass with Brasso _____
(k) Respiration _____
(l) Photosynthesis _____

UNIT OF ANALYSIS:

The research will focus on five randomly selected high schools in the EMDC North (circuit 3), Western Cape Education Department, to conduct the survey.

The actual research will be conducted at one school. I will make use of two grade ten classes, with about 20 learners each, one class will be the experimental group and the other will be the control group.

I will be the teacher-researcher conducting the sessions with the classes, since it will be difficult to get another teacher who is trained to implement Dialogical Argumentation Instruction.

ANALYSIS OF DATA

• Data collected from the survey will be used to determine the status of CAL in the selected schools.
• The data from the interview and classroom observation schedules will be coded and used to give a description of the social background of the learners, the condition of the school and the classroom.
• The results of the SAT will be used to determine the difference in the cognitive achievement in the experimental and the control groups.
ETHICAL CONSIDERATIONS

The respondents will be kept anonymous and all participants of this study will be informed about the final report of this research. Both groups will be treated the same way in terms of content and CAL.

LIMITATIONS

Ways have to be found to address possible contamination of data, because the respondents are at the same school. Another problem that will have to be addressed is the Hawthorne Effect (form of relativity, whereby subjects improve or modify an aspect of their behaviour being experimentally measured simply in response to the fact that they are being studied, not in response to any particular experimental manipulation) to ensure that the findings are the result of the intervention and not something else, like extra help learners might have got, learners’ awareness of the study, the influence of the researcher, etc. I also have to improve the strength of the reliability of the instruments.

Conclusion

Dialogical Argumentation Instruction has a potential role of revitalising science education and to become the core of science teaching. It is hoped that the findings of this study will help to identify problems associated in the implementation of CAL in the selected schools as well as to suggest ways in which the problems can be ameliorated. It is also hoped that the findings would provide useful information about the effectiveness of using a DAI in teaching science concepts or concepts in any other learning area in general.

References:


Problems. Greece: University of Ioannina.

The feasibility of M-Learning (mobile learning) into the chemistry curriculum of high schools in Mafikeng district of South Africa

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Abstract
Rapid changes in ICT (information and communication technology) are leading to development of several opportunities to enhance teaching which were unimaginable a few years ago.
The move towards active, learner centered learning is fast becoming a reality and the
advent of Mobile learning through portable devices will become an important tool in the teaching and learning environment.

The paper explores a novice way of chemistry teaching to high school learners by the use of mobile technologies such as cell phones and smart phones. The present, 21st generation student uses his cell phone 24 hours a day. Hence teachers could harness this opportunity to assist in knowledge transfer, drilling and feedback in Chemistry teaching and learning. The study also embraces a paradigm shift, from normal classroom teaching to anywhere, any time teaching and learning through mobile technology. This report examines the opinion and readiness of the science and mathematics teachers to accept and implement M-learning as a new teaching methodology.

**Key Words:** m-learning, mobile devices, paradigm shift

**Introduction**

Huge strides have been made in various areas of technology and information systems. These advances introduce us to M-learning which offers a new way to deliver learning objects in daily life. According to Steve Vosloo, at Open Innovation Africa summit, Kenya (28th Nov 2010 –Education for all), ‘We need policies that support m-learning and buy in at government and school level. Fresh thinking is needed to support and disrupt existing educational policies.’ (Vosloo 2010)

Students have access to information via the internet and cell phone connectivity and so the parameters of educational knowledge transference have to be redefined. Most mobile devices are useful in education as administrational, organizational and instructional teaching aids for teachers and also as learning support tool for learners. (Balasundaram et al, 2007)

Recently there have been shifts in the mass media from radio and television as a popular source of information to the computer as a knowledge tool (especially with the development of the internet), which now seems to be overtaken by more mobile forms of inventions, such as the notebook computers, tablet PC, PDA (Personal Digital Assistant), I-Pod, cellular phones and smart phones. We focus on the cell phone as the most popular form of transfer of information, and the possibilities that this holds for knowledge transfer in schools both for learners and teachers. The penetration cell phone technology in South Africa is more than 38% and much more is expected as cell phones become more affordable. Younger generations of students are trending away from computer use, as desktops, and even laptops, are considered too unwieldy and location-centric and thus inconvenient. (Mohamed, 2009)

The context of this study may need some clarification. It is based in a rural area of South Africa, in the Mafikeng region. There are a range of schools in the area, from private to government to ex-model C schools. Majority of the learners are mainly from Tswana linguistic backgrounds and come from previously disadvantaged population groups. The teachers involved in this study are professionally qualified and experienced.
Aims and objectives

This paper attempts to explore the notion of mobile learning (M-learning) in the context of the Mafikeng district schools. M-learning may have a broader application in various forms such as ‘tablets’ (wider screen) and PDA (personal digital assistant) and mobile personal computers, but we focus on the developing cell phone technology.

The argument of this paper is that, for effective learning and teaching to take place in the context of the developing world, there has to be a paradigm shift from the traditional ‘chalk and talk’ method to more mobile and flexible forms of learning and teaching (Georgiev et el, 2004 and Ally, 2009). Class room environment is in stark contrast to the outside ICT world. It lacks to excite and develop the learning processes in students. M-learning could change this attitude. It can offer new opportunities for learning beyond the teacher lead classroom. (Traxler, 2009) It has to become part of the mainstream teaching, which will be learner centered, involving both parents and teachers (Stead, 2005). Cell phones seem to morph daily and thus become more user friendly. M-learning has the possibility of transforming traditionally unpopular choice of subjects such as Science and Mathematics amongst high school learners and make them more meaning full and exciting. (Pennington et el, 2009 and Ally, 2009). It can enhance active learning processes among students, rather than being simply passive recipients of knowledge. (Georgiev et el, 2004). It also encourages lifelong learning process, where students can learn by repetition at their own pace. (Muyinda et el, 2008)

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By looking at the above model it becomes evident that informal learning through mobile phones is becoming vital where knowledge sharing is evident. Unlike the computers, the cell phones will enable a learner to navigate and explore more knowledge in a semi formal setting. (Vanska, 2008)

Today’s learner is fast paced, able to multi task and demands immediate feedback. Hence the education delivery and training faces new challenges. It will be forced to keep up with this new trend and delivery learning materials on mobile devices. Mobile devices can also be used to transfer knowledge and learning material to remote areas. New learning materials based on sound educational principals will have to be developed.

An important aspect is that a general social networking tool is redirected towards learning and teaching collaborations, which can add much value to student’s performance,
particularly in traditionally ‘trapped’(Science and Maths) subjects. Such learning bypasses the resistances of cultural and geographical boundaries, making it a neutral tool equally applicable to all learners and teachers. Such things as accents and the manner and style of teaching, or the voice pitch of teachers are also neutralized. M-learning introduces learners to both the concept of inter-disciplinary and lifelong learning.

Methodology

A questionnaire with 22 items was administered to qualified, experienced High School teachers. 11 schools in Mafikeng region were chosen, which were centrally based and easy to access. The total number of science and Mathematics teachers varied in different schools. The responses to the questionnaire were on a Rikert item( strongly agree to strongly disagree.) The questions from 1 to 5 were general question while 6 onwards focused on M-learning and the teachers’ acceptance of this new type of transfer of knowledge. A total of 63 teachers participated in answering the questionnaire.

Breakdown of the different school models which were given the questionnaire.

The schools are broadly of 4 different categories:
1. International school: Private school with a high fee structure, following Cambridge syllabus.
2. Sol Plaatjie,Mmabatho High, and Mafikeng are multi racial and based on former “model C”structure.
3. Letsatsing, a purely science school
4. All the remaining 6 school are state funded, so called public schools.

Schools in category 2, 3, and 4 all follow similar syllabus preparing students for a school leaving certificate examination (NCS).

Data analysis:

The data is analyzed according to the T test for strongly agree (SA), agree(A) against disagree(D) and strongly disagree(SD). (for all the 11 schools)

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<td>9</td>
</tr>
<tr>
<td>94</td>
<td>13</td>
<td>169</td>
<td>34</td>
<td>6</td>
<td>36</td>
</tr>
<tr>
<td>105</td>
<td>24</td>
<td>576</td>
<td>25</td>
<td>3</td>
<td>9</td>
</tr>
</tbody>
</table>
\[
\begin{array}{|c|c|c|c|}
\hline
X_1 = 81 & \sum d_1^2 = 11898 & X_2 = 28 & \sum d_2^2 = 2265 \\
\hline
\end{array}
\]

\[
t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{\sum d_1^2 + \sum d_2^2}{n_1 + n_2}} \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}
\]

\[
= \frac{81 - 28}{\sqrt{\frac{11898 + 2265}{11 + 11}} \left( \frac{1}{11} + \frac{1}{11} \right)}
\]

\[
= 4.7
\]

at 5% level of sig there is a sig diff = 53/11.28 = 4.71

Hence there is a significant difference between those who want M-learning to those who do not want M-learning. Most of the teachers are interested in M learning to enhance teaching and learning environment.

**PROBLEMS**

As the questionnaire was administered during November/December examination period, some of the teacher may not have answered it to the best of their ability. Some teacher also did not understand the meaning of Mobile learning.

The study is also conducted in only a small region of Mafikeng district. It needs to be broadened accompanied by some m-learning topics to be taught for students.

**Conclusions and recommendation**

Mobile learning is already embedded in our present day teaching and learning (Georgiev, 2004). As the mobile technology constantly morphs and cell phones become better equipped to transfer knowledge, M-learning will become appealing to students. Dr Math is one of the M-learning programs, tutoring math to school learner on Mxit. It was started by Meraka Institute and so far 5500 learners have used the service. (Vosloo, 2010). M learning faces many challenges in terms of acceptance in the curriculum, funding from the government and development of sound pedagogical theories. But eventually M learning will be able to overcome all these challenges.

The present day learning environment has been broadened with the advancement in the field of computers and information technology. Hence the learning environment needs to be revised, especially in teaching abstract subjects such as chemistry. M learning in the form of chemistry games would allow students to independently explore the lesson taught. The flexibility of M learning will construct effective learning environment.
REFERENCES


There is widespread agreement that effective teachers have additional unique knowledge to their subject matter knowledge. Often this additional unique knowledge is assigned to the broad, tacit Pedagogical Content Knowledge (PCK) pocket. The question remains whether, within the PCK pocket, is the additional unique knowledge ascribed to the understanding of students and their thinking about a subject, or is it to the special knowledge related to the subject matter knowledge per se. Few scholars have focused on the conceptualization of this additional unique knowledge domain within PCK. A large proportion of these scholars are mostly in the mathematics education field and only a handful in science. It therefore explains the paucity of measuring tools for this unique knowledge domain even when conceptualized. In this article, we make an effort to locate and conceptualize this knowledge domain within science, in chemistry specifically. We build our conceptualization arguments from the understanding that effective teaching is about pedagogical transformation of subject matter knowledge per se. Such transformation emerges from a new, kind of knowledge domain different to that defined in Shulman’s seven categories of knowledge. It is topic specific – we have termed it ‘Topic Specific Knowledge for Teaching’ (TSKfT). The identification of knowledge with transformative powers on subject matter knowledge per se, and the availability of a sequenced process to guide transformation as described by Shulman in his model for Pedagogical Reasoning (PR), has opened an opportunity for the development of a new comprehensive theoretical framework. We termed this – the SMK Transformation theoretical framework.

Although, this is work in progress, we believe that the efforts made here will advance the need for such debates in science education and inform current and future attempts to develop measures.

Introduction

There seem to be agreement that not only do expert teachers possess additional unique knowledge to their subject matter knowledge per se, that this additional knowledge also contributes to their effective teaching (Hill, Ball and Schilling, 2008). The understanding of what specific knowledge domain(s) within those ascribed to PCK, or those unknown but of PCK eminence, yield(s) to effective teaching remains very thin. Few empirical studies with such focus are located in mathematics education and handful theoretical papers in science. We believe that the attempt to conceptualize and the subsequent
development of measures for capturing such specific knowledge domain(s) within the science education field, is of extreme importance. This theoretical paper, presents the conceptualization of a specific knowledge domain within the PCK pocket. The newly conceptualized knowledge domain is further used to develop a new theoretical framework that links Subject Matter Knowledge (SMK) to its transformation and to the reasoning behind its teaching. This combination creates a potential powerful tool for use in design of measuring tools and analysis in future empirical studies.

Conceptualization of A New Knowledge Domain Within PCK

The starting point of our discussion is the acknowledgement of Shulman’s (1986) theoretical idea, that teaching requires transformation of knowledge from a variety of domains, among which subject matter knowledge is central. Also that PCK, as seen in seasoned teachers, is the amalgam of knowledge that enables such transformation to materialize. The benefit for teachers with PCK, is their capacity to transform their comprehension as they pedagogically reason about their teaching. Shulman (1987) described transformation as “the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations inability and background presented by the students” (p. 15).

The view of regarding teaching as involving transformation of SMK has been supported by a number of researchers (Geddis and Wood, 1997; Rollnick et al., 2008; Gess-Newsome, 1999). In exploring the epistemological aspects of PCK, Gess-Newsome (1999) described two models that expert teachers may use to process their knowledge for teaching - the integrative model and the transformative model. For the purpose of this paper, focus will be placed on the transformative model. The transformative model presents PCK emerging from the amalgam of various knowledge domains. This model is also described by Bishop and Denley (2007) in a form of an analogy of a top with different colours representing the different knowledge domains. When, spinning, the colours of the top are mixed portraying one single colour, of the PCK. Meaning, by mere having the various knowledge domains by themselves with no ‘transformation processing’ PCK will not emerge. Geddis et al. (1993) asserts that it is important to “articulate the knowledge needed to perform such a transformation” (p. 675). At present, the transformation model is widely accepted as a mechanism for the emergence of PCK, however, is not fully developed to define the knowledge domain(s) needed to effect the transformation itself. This paper sets the ball rolling in conceptualizing the knowledge domains with SMK transformative powers.

In order to articulate the knowledge enabling transformation of SMK, the knowledge base accessed by a teacher as a foundation for her knowledge is first described. It is based on Shulman’s (1987) seven categories of knowledge, namely, Content knowledge; General pedagogical knowledge; Curriculum knowledge; Pedagogical content knowledge (PCK); Knowledge of the learners; Knowledge of educational contexts; and Knowledge of educational ends, purposes, and values and their philosophical grounds. Shulman considers the PCK category as the most enabling. In describing PCK he hints at another type of knowledge – subject matter knowledge for teaching. He distinguishes this knowledge from PCK as concerned with the ‘aspects of content that are most germane to its teachability’ (Shulman, 1986, p. 9). However, Shulman appears not to
have perceived this kind of knowledge as a domain sharing the same stature in the
teacher's knowledge base, as it is excluded in his list of knowledge categories. He did
not define it as PCK either, but referred to it as reflecting knowledge linked to SMK with
respect to its teachability. Unfortunately, his discussion on subject matter knowledge for
teaching provided no examples of the components of such knowledge. On the other
hand, Geddis and Wood (1997), argue that as a consequence of the view that teaching
involves transformation of SMK, different kinds of knowledge from which subject matter
transformation emerge are observed (p. 612). These include: i) learners' prior
knowledge including the preconceptions about a topic; ii) effective teaching strategies;
iii) alternative representation of the subject matter; iv) importance of the topic to the
overall chemistry curriculum - 'curricular saliency'; and v) what makes the topic easy or
difficult to understand.

While Geddis and Wood (1997) did not give a title to these different kinds of knowledge,
the authors clearly distinguished between these and subject matter knowledge per se, and
emphasized their pedagogical transformative effect on SMK. In mathematics, Ball and
her colleagues (Ball et al., 2008;) have conceptualized and spearheaded the notion of
knowledge for teaching mathematics through a collection of empirical studies where they
analyzed the core activities of mathematics teaching of specific topics (e.g.
multiplication, fraction, and division). What surfaced from their analysis was the
evidence that teaching may require a 'specialized form of pure subject matter'. Ball's
argument for referring to such knowledge as 'specialized' includes the fact that the
knowledge demonstrated by teachers in explaining operations was mainly related to
subject matter but beyond mere algorithms commonly known to all other professions
using mathematics. ‘..Specialized Content Knowledge (SCK), is the mathematical
knowledge and skill unique to teaching’ Ball, et al. (2008, p. 400). Her work in this line
of thought has gone further in identifying, empirically, what such knowledge in
mathematics may contain: i) Error analysis; ii) Mathematical reasoning; iii)
Mathematical Language; iv) Common students’ conceptions and misconceptions about
particular mathematical content; v) Mathematical knowledge of the design of instruction;
vii) Teachers’ understanding of sequencing particular content for instruction; and vii)
Horizon knowledge.

While education researchers like Shulman, Geddis and Ball refer to, and locate the above
kinds of knowledge differently, they however have in common a set of various
knowledge types that enables transformation of SMK for purposes of teaching. In
looking closely at this set, it is noticeable that it differs from the seven category of
knowledge domains ascribed to PCK. The most conspicuous distinction is the exclusion
of subject matter knowledge per se, a central aspect to PCK. This set of various
knowledge types is an amalgam - of different knowledge affecting teachability of SMK.
The amalgam talks to deconstruction, re-structuring, sequencing and representation of
SMK with the purpose of accessibility by students. We posit that the process of
deconstruction and re-structuring is repeated for each topic of SMK, as each teaching
instruction has been argued to be a transformation of the SMK being taught. Therefore
each topic of SMK, needs the listed amalgam talking specifically to it and therefore
transforming the topic pedagogically. We have termed this ‘amalgam’ – Topic Specific
Knowledge for Teaching. Good understanding of a specific topic of subject matter knowledge per se, will not transform it for understanding by learners. It is the understanding of the ‘topic specific amalgam’ – Topic Specific Knowledge for Teaching (TSKfT) – that provides the needed knowledge for the transformation of subject matter per se. Perhaps it is this topic specific amalgam that makes PCK topic specific in nature as reported by various researchers from empirical studies (van Driel et al., 1998). While Geddis and Wood, and Ball et al. have formulated the components of TSKfT differently as described above, there are, however, common elements making the formulations similar in many aspects. The similarities include listing of: i) teaching strategies (not pedagogy but considerations related to SMK), ii) curriculum saliency, sequencing of content for instruction and iii) representations. There is also a major difference between the two formulations. The major difference is the fact that Geddis and Wood have included consideration of students’ prior knowledge, yet Ball et al. argue that SCK is purely related to content knowledge technicalities without reference to knowledge about students. We therefore pulled the composition of TSKfT as follows (see Table 4.1 below):

Table 4.1: The Nature of TSKfT

<table>
<thead>
<tr>
<th>Knowledge types from which SMK transformation emerges: Geddis &amp; Wood (1997)</th>
<th>'Specialized Content Knowledge': Ball et al. (2008)</th>
<th>Topic Specific Knowledge for Teaching</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learners’ prior knowledge</td>
<td>Error analysis.</td>
<td>Error Analysis</td>
</tr>
<tr>
<td>Effective teaching strategies</td>
<td>Mathematical reasoning.</td>
<td>Learners’ prior knowledge</td>
</tr>
<tr>
<td>Alternative representations</td>
<td>Mathematical Language.</td>
<td>Effective teaching strategies</td>
</tr>
<tr>
<td>Curricular saliency</td>
<td>Conceptions and misconceptions</td>
<td>Alternative representations</td>
</tr>
<tr>
<td>What makes the topic easy or difficult to understand</td>
<td>Design of instruction.</td>
<td>Curricular saliency</td>
</tr>
<tr>
<td></td>
<td>Horizon knowledge</td>
<td>What makes the topic easy or difficult</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Powerful analogies and examples</td>
</tr>
</tbody>
</table>

The newly formulated model of TSKfT includes knowledge of learners’ aspects such as learners’ prior knowledge and teaching strategies that are absent in the model by Ball et al. The consideration for inclusion of student’s prior knowledge in TSKfT, is to align with Shulman’s (1986) view of SMK transformation for the purpose of benefitting the learners. Thus the formulation of TSKfT leans more towards Geddis and Wood’s model. In looking at the formulated list, one notices that TSKfT is regarded as everything about PCK that is explicitly related to subject matter knowledge. This observation is in sync with Shulman’s descriptions of subject matter knowledge for teaching..that is ‘aspects of content that are most germane to its teachability’ (Shulman, 1986, p. 9). It therefore appears that for SMK to be transformed effectively, knowledge about its aspects as described in TSKfT are needed as tools.

In granting that the TSKfT knowledge domain is more related to SMK than any of the knowledge domains ascribed to PCK, it has been important to find a location for it, with respect to the other knowledge domains and PCK itself. Figure 4.1 provides a visual location of TSKfT. The illustration has been adapted from the PCK model by Rollnick et al. (2008). In this model, PCK emerges from the amalgam of student context, student knowledge, subject matter knowledge and pedagogical knowledge domains. All these
domains are underpinned by the teacher’s beliefs. The main adaptation to the model is the inclusion of TSKfT, as a knowledge domain from which transformation of SMK emerges and is, therefore, a connecting link between SMK and PCK. The link of TSKfT to aspects of student knowledge such as prior knowledge is illustrated by a faint line, as the original Student Knowledge domain is not considered to be transformed by TSKfT. However, the line reflects the fact that aspects of this domain are part of the different knowledge types that constitute TSKfT.

Figure 4.1: The Topic Specific Knowledge for Teaching –PCK Model

The conceptualization of a special knowledge domain within PCK, that has pedagogical transformative effects on SMK, could be opening a window into understanding the observed lack of PCK, and therefore ineffective teaching in cases where candidates have strong SMK as a result of their mainstream scientific background. Opportunities for further empirical studies in this regard are opening.

Reasoning About Teaching

Good teaching is not only about knowledge but also the capability to reason soundly about teaching. Sound reasoning by teachers requires both a process of thinking about what they are doing and an adequate base of facts, principles and experience from which to reason. Shulman (1987) presented a theoretical framework entitled ‘Pedagogical Reasoning and Action’. The framework was derived from an empirical study of expert teachers. It consists of aspects of reasoning, starting with Comprehension, followed by Transformation, Instruction, Reflection and finally a New Comprehension. Shulman is less explicit on how these components may interact mathematically; however, the framework offers an opportunity of analyzing the teaching process that gives particular prominence to the idea of transformation of subject matter. In this paper we have
adopted the sequential representation by Bishop and Denley (2007) in discussing this framework. However, we remain cautious that the reasoning process may not always be sequential. Nonetheless, the sequential nature provides a platform for the study to discuss and analyze each component, specifically the transformation component and its sub-categories as they are of interest to this study. The discussion below looks selectively into the steps of the Transformation platform as it is of importance to the study.

Transformation
According to Shulman, transformation requires a combination of processes, each of which employs a repertoire: These processes are: i) preparation that requires critical interpretation, ii) representation of ideas in the form of new analogies, metaphors etc, iii) instructional selection from an array of teaching methods, and vi) adaptation of these representations and tailoring for a specific learner audience. These processes enable the teacher to move from personal comprehension to preparation for comprehension of the other. They result in a plan to present a lesson. We note with interest the reference to the knowledge elements contained in the Topic Specific Knowledge for Teaching (TSKfT) domain. The steps in Transformation platform are further discussed here to highlight the links with TSKfT.

(a) Preparation
The process of ‘preparation’ involves “examining and critically interpreting materials of instruction” in order to detect errors and restructure the material into a form that is suitable for teaching (Shulman, 1987, p. 102). This draws on TSKfT.

(b) Representation
The process of representation involves deciding what multiple forms of “analogies, metaphors, examples, demonstration, simulations and the like” would best represent the ideas to learners (Shulman, 1987, p. 103). This again requires the teacher to draw on TSKfT.

(c) Selection
The teacher draws on his or her repertoire of instructional modes to select an instructional form or strategy that would be appropriate in the teaching of the particular lesson. Shulman (1987) suggests that such a repertoire could include “not only the more conventional alternatives such as lecture, demonstration, recitation, or seatwork, but also a variety of forms of cooperative learning such as reciprocal teaching.

(d) Adaptation and tailoring
The final steps in transforming the content for teaching involve “fitting the represented material to the characteristics of [learners]”. In adapting the represented material to learners, the teacher may consider “aspects of [learner] ability, gender, language, culture, motivations, or prior knowledge and skills” (Shulman, 1987, p. 103).

Looking at the descriptions of the repertoires making up transformation, there is an almost total overlap between these processes and the amalgam of knowledge described as Topic Specific Knowledge for Teaching -TSKfT. Both these constructs refer to the
need for ordering and re-arrangement of learning in consideration of what is too difficult
or easy or repeated about the curriculum to achieve most understanding; the need for
representations and analogies in consideration of accuracy and students; selection of
appropriate instructional strategies or alternative strategies; and adapting and tailoring
of the represented knowledge so that it fits the characteristic of the students - either
based on student prior knowledge or backgrounds and contexts. The observed synergy
fit draws one to enquire about a possible inter-relationship framework between the
‘knowledge conceptualized to transform SMK and the Reasoning about its teaching.

The SMK Transformation Theoretical Framework

The theoretical framework proposed for this study, draws on two theoretical ideas,
namely, the Pedagogical Reasoning (PR) model with its prominence in the concept of
pedagogical transformation; and the Pedagogical Content Knowledge (PCK) model that,
that has been extended in this study to give prominence to Topic Specific Knowledge for
Teaching (Figure 4.1 above). The PR model provides the reasoning process about
teaching, while the Topic Specific Knowledge for Teaching -PCK model provides the
knowledge aspects of teaching. The focus of this discussion is now placed on the inter-
links that these ideas offer. The starting point of the PR process is the ‘comprehension’
of Subject Matter Knowledge. As discussed previously Shulman (1987) places high
priority to understanding of subject matter knowledge by teachers before teaching it.
Similarly, subject matter knowledge per se, also enjoys a central role within the amalgam
of teacher knowledge (PCK) domains (Shulman, 1987). The positioning of
‘comprehension’ as a starting point in the PR model is equated to the emphasis of
centrality of ‘subject matter knowledge’ in PCK. The resulting inter-link is highlighted
by the arrow line in Figure 2 below. The next platform in the PR model is
‘Transformation’. This is the crux of the Theoretical Framework for this paper.
According to the PR model, transformation of ‘comprehension’ happens through a
repertoire of steps where preparations, representations and adaptations’ are made in
consideration and in favour of the learner to receive the teaching. On the other hand,
the PCK model presents transformation of SMK, as emerging from an amalgam
of knowledge related to SMK that are specific to the topic being taught. Both models offer
different but complementary lenses for viewing transformation of subject matter
knowledge. By combining the two models, the resulting lens is a more powerful tool as it
allows analysis from both the process and knowledge perspectives. The repertoire of
transformation steps of the PR process on the left are linked to the knowledge aspects of
Topic Specific Knowledge for Teaching in the PCK model.
The next stages of the PR model talks to the actual instruction and the evaluation and reflection that a teacher does. These stages are linked to the other knowledge domains of PCK that draw on knowledge of students, contexts, pedagogical knowledge and beliefs. According to Shulman (1987), on completion of the Pedagogical Reasoning process, teachers have developed new comprehension for their learners and for themselves.

Conclusion

Firstly, the conceptualization of the new domain within PCK, that may be linked to pedagogical transformation of SMK, advances the notion that the additional, unique knowledge associated with effective teaching, is more related to SMK than to the Student Knowledge domain of PCK. Also that this additional, unique knowledge is topic specific. It is to be considered and understood for each major topic of science. Secondly, the merging of the two theoretical ideas (Pedagogical Reasoning Model and Topic Specific Knowledge for Teaching –PCK Model) displays a synergic fit, supporting the discussions about PCK, SMK and its transformation. On the basis of the displayed inter-links that reflect the equivalence of the respective components of the PR-PCK framework, it is therefore reasonable to interpret the evidence for the presence of Pedagogical Reasoning with its prominence in transformation as the presence of PCK, and vice-versa, the presence of evidence of TSKfT as the presence of transformation of SMK, and therefore
PCK. This theoretical tool provides a base for the development of measuring tools that can advance empirical studies on PCK and its development.

References


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Investigating the nature of epistemological access afforded by a first-year chemistry intervention programme

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This paper describes a study informed by a general concern to capture innovative and effective practices in higher education. The research seeks to investigate the nature of epistemological access afforded by a first-year chemistry intervention programme, with an ultimate aim of contributing to the development of effective spaces for learning in higher education. The study is regarded as dynamic in terms of its emergence from, and its intended contribution to, practice. The outcome of this somewhat emergent process not only suggests relevant and useful insights into educational practice in higher education but also offers appropriate and meaningful insights into constructive ways of conducting research. It is hoped that this research will contribute to the field both pedagogically as well as methodologically.

Introduction

This paper describes a study informed by a general concern to capture innovative and effective practice in higher education. The intention underlying this study is to conduct research which seeks to understand and inform and ultimately to contribute to the development of effective spaces for learning in higher education. The study is regarded as dynamic in terms of its emergence from, and its intended contribution to, practice. The motivation was interest in understanding the efficacy of a specific context, with the intention of insight gained being used to inform other similar contexts. The specific aim of this research project was to develop an understanding around how the teaching and learning context of an intervention programme in first-year Chemistry (Chemistry 1R) supported effective student learning, specifically in relation to affording or facilitating epistemological access.

The outcome, of what was a somewhat emergent process, we believe not only suggests relevant and useful insights into educational practice in higher education but also offers appropriate and meaningful insights into constructive ways of conducting research. Echoing a participatory mode claimed as an essential characteristic of the learning and teaching context, the approach taken here is one not just of participation, but rather partnership. The context of higher education offers a space in which colleagues can collaborate on research projects from positions of equity in terms of the knowledge and skills they bring to the context. While the collaborators might be operating in different discipline arenas (in this case – education, mathematics education and chemistry), they share a common interest in research as well as practice, offering a strongly praxis-orientated milieu conducive to rich and rigorous research. While this study has afforded insights into a specific case supporting learning in higher education, it is also anticipated that it will encourage the proliferation and interrogation of further positive and constructive interventions around specific practices in higher education.
Research context and background

Over the past two decades the South African higher education system has seen both expansion and restructuring. This has in part been an attempt to meet the imperatives of equity and redress in relation to past injustices, but it has also been a response to global demands in terms of development and massification. The expansion of the higher education system has seen a dramatic increase not only in terms of student enrolment, but also in the diversity of the student body. However, there is an urgent necessity that such expansion and widened access is not accomplished at the expense of quality and academic standards. As Bak (1998:204) sums up, there is a requirement for higher education institutions to develop “teaching and learning strategies that will ensure an increased yield of quality students drawn from a large and diverse student body.”

The present study emerged in response to the identification of a unique situation exhibiting evidence of being successful in terms of its aim to support the throughput of first year chemistry students who were unsuccessful in the preceding semester of their studies. The Chemistry 1R programme at Rhodes University runs six months out of phase with the Chemistry 1 course. Unsuccessful students are afforded the opportunity to review the course content in the tutorial-like supportive environment of a smaller class. Due to the increased number of students being placed in the Chemistry 1R programme in the second semester of 2009, a second person was appointed to assist with the teaching of Chemistry 1R for the period July 2009 to June 2010. A team-teaching strategy was adopted, and this led to an emergent and collaborative research project centred on investigating the nature of epistemological access afforded by the Chemistry 1R intervention programme.

The two people involved in the team teaching both have formal qualifications in Chemistry, but have different teaching backgrounds. Joyce has been teaching the Chemistry support tutorials since 1989, has taught the Chemistry 1R course since its inception in 1993 and is embarking on doctoral research in Chemistry education. Duncan has been teaching Mathematics at the school level since 2002 and is in the process of conducting research in Mathematics Education for his doctoral degree. Joyce and Duncan are also involved in the development of Mathematics and Science school teachers.

Both Duncan and Joyce were present at every lecture and tutorial. Each elected to introduce and teach the topics with which they felt most comfortable. Thus, material would be introduced in a formal lecture-type setting and then problems would be set for the students to attempt for the rest of the lecture. During this time the two lecturers would circulate throughout the lecture venue to help individual students who were struggling with the work. The solution to each problem would then be developed on the board so that all students could see the solution process and be aware of the skills needed to tackle such problems.

The lecturers were both aware that because students had been placed in the Chemistry 1R programme, it was highly likely that most students would have a low chemistry self-concept, and some would not have adapted to the “culture” of studying chemistry at University (Angel and LaLonde, 1998). Angel and LaLonde (1998) found that students who were not strong in mathematics and science benefit from advice and encouragement.
It was thus recognised that it was important for students to feel comfortable to ask questions during the lecture time as well as while doing the problems and to feel comfortable to ask for an alternative explanation from the other lecturer if they did not understand one’s explanation. Both lecturers also felt comfortable to offer alternative general explanations if they could see a different way of tackling a problem. Wherever possible, the context of the Chemistry topic was explained and class demonstrations were conducted.

**Conceptual orientation**

The notion of access has become a critical issue in higher education for the reasons outlined in the research context and background. When discussing access, it is important to distinguish between what Morrow (2007) refers to as formal access and epistemological access. While formal access relates to the various policies which allow for legal registration at an institution, epistemological access has to do with engaging students with the practices and specialised discourses of the discipline.

As Morrow (2009:77) critically points out, formal access to higher education institutions is not on its own necessarily a sufficient condition for epistemological access. Intricately tied up with the notion of access is that of agency. Epistemological access is not something that can be delivered or transmitted to a passive student. Morrow (2009:78) articulates the reason for this by describing epistemological access as “learning [emphasis added] how to become a successful participant in an academic practice.” In the sense that each student is ultimately the agent of their own learning, so too are they the agent of their own epistemological access. There are of course any number of things that could aid the process, or make the process more effective, but at best this will only facilitate epistemological access, it will never guarantee it (Morrow, 2009).

As Bak (1998:206) comments, the broadening of epistemological access is the domain of teaching and learning strategies. In addition, Bak makes the pertinent point that epistemological access needs to be coupled to the notion of epistemological labour, a concept that links closely with Morrow’s notion of agency. A critical aspect of facilitating epistemological access within higher education rests on the development of teaching and learning strategies that take into account a rapidly increasing student body drawn from diverse backgrounds (e.g. language, culture, quality of schooling, etc.) while at the same time maintaining academic standards and being respectful of learners’ efforts to achieve epistemological access.

**Theoretical orientation**

At the meta level this research is underpinned by a critical realist orientation, recognising the layered nature of reality. The focus of this paper is on the empirical. The purpose of the research is thus not to gauge the success of the intervention initiative per se, but rather to engage with the experiences of the individuals who were part of the intervention programme, the meanings they made of their experiences and how the experience might be contributing to their learning and supporting epistemological access. The research was consciously approached through a lens of redress and transformation. As Bhaskar (1989:271) comments, at its core, “critical realism rests on the assumption that the accounts of the research participants are valid scientific data that can lead to
consequential social transformation if properly interpreted.” The intention is to understand in order to inform both inherent and potential transformatory realisations.

At the substantive level, the central concept of learning is framed with reference to Illeris’ Contemporary Learning Theory (2001). This theory, Illeris claims, rests on two fundamental assumptions. Firstly, that learning involves two essential processes both of which ‘have to be actively involved if any learning is to take place’ (2001:3): an external interaction process between the learner and their environment, and an internal cognitive process of acquisition and elaboration where new concepts are linked to already held understandings. Secondly, learning involves three dimensions: cognitive (knowledge & skills), psychodynamic (motivation, emotion and attitude) and social (communication and co-operation). Illeris’ triadal framework of dimensions offers an overarching framework for the multitude of learning theories which deal with different aspects of learning, positioning each in an overall ‘structure of the landscape of learning’ (2001:1). This framework proved useful in framing the data that emerged from the project, and a multilayered process of analysis was informed by these three dimensions of learning.

Research design and discussion

This research may be described as interpretive in intention, responsive in terms of motivation and development, active in terms of its potential for development, and both collaborative and deliberative in terms of the methodological process.

Data generation

The data generation unfolded in three phases. An initial anonymous questionnaire was completed by the students focusing on their experience of learning in the Chemistry 1R context, with particular reference to the team-teaching approach employed. These responses were collated and synthesised, a process which in turn informed the design of a simple framework for a focus group discussion which interrogated in more depth the central themes emerging from the initial data. The final phase, the individual interview, was designed to elucidate deeper insights and understanding relating to the specific context under investigation.

The data generation instruments were developed collaboratively by the research team, allowing for greater critical and more holistic engagement. The facilitation of the data generation was conducted by the third member of the research team (Sue), a Higher Education Development Practitioner, creating an important distance between the students and the lecturers to ensure greater data validity. It also helped to avert the potential of the study being a self-validating project. While the inter-subjective nature of such a study is recognised and celebrated, the involvement of all three researchers in the analysis of the data contributed to a richer and more rigorous engagement.

Data analysis & discussion

This paper reports on the analysis of data stemming from the first two phases of the data generation process (the initial anonymous questionnaire and the focus group discussion).

Phase 1 – anonymous questionnaire

The purpose of the initial questionnaire was to evaluate the Chemistry 1R course which ran during the second semester of 2009. A number of broad themes emerged during the
analysis of the student responses. These included a heightened sense of enjoyment and interest in the study of Chemistry, improved levels of understanding, a positive learning experience, and an appreciation for the diversity of the context afforded by the team-teaching model.

A strong thread running through the responses related to the manner by which the team-teaching approach was able to create spaces for greater individual attention and the enablement of understanding. The students particularly appreciated the more hands-on approach and the way in which one of the lecturers would move around the class providing one-on-one assistance to students while the other carried out the more formal aspects of teaching. Improved understanding was in part attributed to the increased interaction between lecturers and students. Furthermore, it was recognised that the level of attention and interaction were directly related to the adoption of a team-teaching approach.

There was also a strong appreciation and celebration of the diversity afforded by the team-teaching context. The students appreciated having different people teaching different things in different ways, offering alternative approaches, solution methods, opinions and perspectives, all of which were cited as contributing to a broader and more thorough understanding of the course.

Students expressed strong feelings about the method of team-teaching: ‘I believe that the ‘Team’ allows for much better and effective teaching’, ‘I think that ‘team teaching’ has been the best style of lecturing here at Rhodes’. In fact, it was even suggested that ‘this is how all subjects should be taught and not only be implemented after students have failed’.

Phase 2 - focus group discussion

An analysis of the second layer of data allowed the central themes which emerged from the first layer to be interrogated in greater depth. We were particularly interested in furthering our understanding of issues specifically surrounding the team-teaching model in order to gain deeper insights into the nature of the epistemological access afforded by this model.

A strong theme running through the responses related to the supportive and relaxed atmosphere created by the tutorial-like environment of a smaller class in which students and lecturers are able to get to know each other to a greater extent. This not only assisted in creating a more comfortable learning atmosphere with a ‘discussional’ feel, allowing hesitant students to ask questions more easily, but was important in enabling and supporting important affective domains such as confidence, enjoyment and motivation. ‘Chemistry became more interesting and easy to understand’, ‘We as students are really comfortable and relaxed’, ‘They have made Chemistry very exciting’.

Having two lecturers as opposed to just one had a number of important practical benefits. Students recognised that the team-teaching model enhanced the level of interaction between students and lecturers as well as enabling the provision of greater individual attention, particularly when the class was engaged in working through example problems and exercises – ‘Having two lecturers makes it easier to get the individual attention we want’, ‘It is as close to a one-on-one experience you can get in undergraduate’. Students
also appreciated that the team-teaching approach made it possible to be ‘individually attended to in class while that particular section is being taught’, thus enabling students to ask about their problem ‘straight away, and not have to wait until the end of the lecture’.

Another strong thread running through the responses concerned the advantages afforded by the differing backgrounds, viewpoints, experiences and complementary teaching styles of the two course lecturers. ‘By having different ways of explaining the same thing you are able to understand it better yourself and have more than one way to go about a certain problem’. Students appreciated having access to different explanations, alternative ways of grasping concepts, and different approaches to solving problems, all of which led to enhanced communication between lecturers and students, and heightened understanding of important concepts. ‘It helps me to understand every concept better because if I didn’t really understand how Mrs Sewry (Joyce) taught something then I can ask Duncan to explain to me in another way’. In addition, having two lecturers with different but complementary teaching styles was cited as strengthening the class’s overall confidence towards the subject.

It became apparent that the three broad strands – cognition, socio-cultural, and affective – were intimately linked, and each had an influence in terms of facilitating epistemological access. Figure 1 attempts to capture this dynamic interdependence.

Figure 1. Triadic framework of strands facilitating epistemological access.

A number of insightful comments made during the focus group discussion led to a deeper appreciation of the complementary roles played by the two course lecturers. ‘Duncan is more of a teacher and Joyce is more of a lecturer and people love that because there are
things better explained by Joyce and some by Duncan and knowing that they are always there to explain helps with our understanding’. ‘Duncan has got a mathematical background and is very good with numbers and explaining them, while Mrs Sewry (Joyce) is very good with the theory … so their different strengths made the interaction and understanding better. You get to understand both theory and numbers clearly’. It would thus seem that epistemological access was facilitated not only by the complementary backgrounds and experiences of the two lecturers, but at least in part because this complementarity was effective for some students in smoothing the transition from school classroom to university lecture theatre and the associated changes in mode of delivery – i.e. from classroom teaching to university lecturing. These comments suggest important implications for the staffing of intervention programmes and foundation courses. The careful and critical choice of course lecturers/facilitators has the potential to create enhanced learning experiences impacting on the cognitive, affective and socio-cultural domains of students, thus facilitating epistemological access.

A further consideration suggested by the present research is that splitting a relatively large class into two smaller classes may not necessarily be the most appropriate course of action in terms of effective learning and teaching. Although it might be assumed that splitting a class into two smaller groups, each with their own lecturer, would lead to greater individual attention and more meaningful student-lecturer interaction, this assumption doesn’t recognise or appreciate the potential richness which could emanate from the complementary roles of two lecturers team-teaching a single large class.

Another interesting comment made by a number of students was that the team-teaching model adopted in the Chemistry 1R course afforded the two lecturers the opportunity to present those sections of the course that they either particularly enjoyed, or which more closely resonated with their particular strengths. It was suggested that this enhanced the lecturer’s passion which in turn led to greater engagement and understanding on the part of the students.

Concluding comments

It is important to note that the research presented here is regarded as a pilot study, both in terms of its depth and scope, as well as the emergent and exploratory approach regarding involvement and dynamics around the research relationships. Nonetheless, we believe that the outcome not only suggests relevant and useful insights into educational practice in higher education but also offers appropriate and meaningful insights into constructive ways of conducting research. It is thus hoped that this research will contribute to the field both pedagogically as well as methodologically. While this study has afforded insights into a specific case supporting learning, it is also anticipated that it will encourage the proliferation and interrogation of further positive and constructive interventions around specific practices in higher education.

References

Evaluation/ Impact assessment study of the Chemistry student laboratory project

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Abstract

The evaluation is about the implementation of a project aimed at testing the impact of the chemistry project in the secondary schools of the NorthWest Province. The selection of the sample followed a proportional random procedure. It was estimated that a sample of 400 learners was required in order to ensure adequate power of the analyses and generalizability. This sample comprised of the treatment group of learners who have experienced the chemistry programme to various extends in grades 11 and 12.

The assumption was that the project will involve schools in a good deal of fundamental rethinking of the curriculum and this was more likely to show up in schools where the project has long been established. The interest was in the growth of learner performance through the programme which was offered in grades 10, 11 and 12. Since the evaluation was conducted in September 2006, performance was examined in grades 11 and 12 in both project and non project schools.

The performance assessment tasks involved 10 learners from each grade in each school. The learners (5 boys and 5 girls) were chosen from the class list that was made available to the administrators. The performance assessment tasks were administered in 40 schools involving a total of 800 learners. The sampled learners also completed the attitude
questionnaires to solicit their attitudes towards chemistry. In addition, the administrators also interviewed curriculum specialists and university lecturers who were involved in the training of educators. The educator questionnaire was also administered to the project educators. This data was used in answering the general evaluation questions relating to the achievement of the project goals and options for the future of the project.

Results indicate that learners with more positive attitudes towards chemistry are more chemistry literate. The attitude and literacy scores for project schools were higher than those of non-project schools. This was hypothesized to be the case at the beginning of the project and is the major finding of the evaluation, verifying the project in terms of its goals and to increase chemistry literacy through the study of chemistry education. The project educators and curriculum specialists had a quite positive attitude towards the training they received, both in content and organization. Concern was expressed with regard to how the training related to the National Qualifications Framework, and what formal qualification will result from the training.

1. BACKGROUND AND TERMS OF REFERENCE

Over the period 2003-2006, the North West Department of Education has provided funds in support of the Chemistry Student Lab Project. The goal of the project was to support scientific human resource development in the province by assisting the improvement of the quality of chemistry education. The Chemistry Student Lab Project began in 2003 with the selection of 112 schools, the training of educators and the teaching of learners in Grade 10. In 2004 the project grew to include 115 more schools. In 2005 another 228 schools were supplied with the kits. In 2006, 455 schools were involved across grades 10, 11 and 12.

Booklets (worksheets and content modules), video cassette and mini chemistry lab kits were provided as educator support material. Educator training consisted of working through the books and kits. Lecturers from the Chemistry Department of North West University (Potchefstroom Campus) were responsible for the training of educators as well as the development and supply of the kits.

The objectives of the project were to enable educators and learners to:

- Be able to identify a problem and devise a plan of action to solve it,
- Be able to process data,
- Apply the scientific method of reasoning and scientific procedures to acquire data,
- Observe carefully and correctly the changes occurring during chemical processes,
- Develop manipulating skills by experimenting on their own,
- Construct the correct visual images necessary for the formation of concepts and models,
• Be able to give a scientific explanation for the phenomena that fall within their field of study,
• Be able to write down their observations,
• Develop a positive attitude towards chemistry and the natural sciences as a result of their experimentation, observation, interpretation, peer learning and group work, and
• Be conscious of the use and misuse of chemicals and chemistry

A significant feature of the project is the partnership between the Department of Education and North West University. The Professional Support Services Chief Directorate commissioned the Quality Assurance Chief Directorate to undertake an evaluation of the Chemistry Student Lab Project, on 01 September 2006. A major objective of the evaluation has been to make recommendations as to the nature of any potential future funding of the project. The empirical report would serve as a strong empirical data to decide if the project should continue or not.

Following discussions with Professional Support Services Chief Directorate, the specific brief for Quality Assurance was agreed to centre on the impact that the project has had in schools, on educator, subject advisors and learners and on project implementation issues concerning for example the training and preparation of educators. As part of this evaluation, we as Quality Assurance have been asked to make a judgment of overall project success by choosing one rating from the following scale:

**Highly successful:**

Objectives/outcomes completely achieved or exceeded and very significant benefits in relation to costs

**Successful:**

Objectives largely achieved and significant overall benefits in relation to costs

**Partially successful:**

Some objectives achieved and some significant overall benefits in relation to costs

**Unsuccessful:**

Objectives unrealized and no significant benefits in relation to costs

**Largely unsuccessful:**

Very limited achievement of objectives and few significant benefits in relation to costs

In making this judgment we have been asked to provide a full commentary in and justification for our conclusions and to make recommendations on future strategies for
North West Education Department support of the Chemistry Lab Project.

Theoretical framework

Constructivism provided the theoretical framework for this study because learning by doing and simulations of occupations are the basis for much of the instruction in Science education. Although constructivism is not a theory of teaching, it suggests taking a radically different approach to instruction from that used in most schools. The best way to learn is not from lectures, but by letting learners construct knowledge for themselves. Learners should have a constructivist educator along with a constructivist classroom to help them discover new things for themselves. Constructivism promotes increased social interaction and discussion in the classroom, both between educators and learners and between learners.

2. EVALUATION QUESTIONS

This evaluation was designed to provide guidance with regard to the future of the project, given that NWED financial support will cease after 2006. The terms of reference for the evaluation research arose from an examination of the original goals of the project.

The evaluation questions are:

What impact does the project have on learners’ concepts and attitudes towards chemistry?

- Do Grade 12 learners have significantly more positive attitudes and concepts about chemistry than grade 11 learners?
- Do learners participating in the project have significantly more positive attitudes and concepts about chemistry than other learners?
- Does the 2005 project group have significantly more positive attitudes and concepts about chemistry than the 2004 pilot group?
- What are the attitudes of educators towards chemistry student lab project?

What impact does the project have on learners’ performance in chemistry?

- Do Grade 12 learners know significantly more about chemistry than Grade 11 learners?
- Do learners participating in the project know significantly more about chemistry than other learners?
- Do the 2005 group have more sophisticated ideas about chemistry than the 2004 pilot group?
- Are there significant gender differences within the learners?

Is there a significant difference between males and females in their concepts and attitudes towards chemistry?
Is there a significant difference between gender differences between the treatment and the control groups?

To what extent have the goals of the project been achieved?
What is the projected future of the project?

The collection of data to enable the evaluation questions to be answered involved both the qualitative and quantitative methodologies.

3.1 QUALITATIVE METHODOLOGY
Qualitative data was collected from descriptive documents about the project and from a structured interview process with people representing interested parties in the project. These included the subject advisors, educators of participating schools and Potchefstroom Chemistry Department features. This group represented a purposive sample, selected within the time and space limitations of the evaluation schedule and to ensure input from all representative groups. This data had been used to assist in answering the general evaluation questions relating to the achievement of the project goals and options for the future of the project.

3.2 QUALITATIVE METHODOLOGY
The main thrust of the quantitative methodology involved a comparison between learners who had participated in the project and other learners who had not participated, through the selection of treatment and control groups in the sample. An additional helpful methodology would have been a pre-test/post-test longitudinal design, but this was not feasible because of the absence of comparable initial data. A quasi-longitudinal design was possible by making comparisons between learners who had been in the project for a number of years (grade 12 learners) and those for whom this was their second year (grade 11 learners). The other aspects of the methodology revolved around the effect of the independent variables on the dependent variables in a number of combinations.

3.3 VARIABLES
The dependent variables were represented by two instruments which were administered to the learner sample, namely attitudes about chemistry and the performance assessment task. The independent variables considered were gender, treatment and grade. These are summarized in Table 1.

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Chemistry literacy and knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Attitudes about chemistry</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Independent variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
</tr>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>Grade</td>
</tr>
</tbody>
</table>

Table 1. Variables
4. INSTRUMENTS

The instruments used in the evaluation were designed and developed by Science Subject Specialists in the Quality Assurance Chief Directorate. The instruments were graphically designed, rechecked for face and internal validity, modified and printed. They were then administered to the selected sample.

5. TASK VALIDITY

The question of validity is notoriously difficult but very important. If we wish to claim that our activity is valid we are making a claim that if learner does well at it, it is because they are good at chemistry. If they do poorly at our activity, it is because they are poor at chemistry. We would wish to claim that our activity is a valid predictor of real technological performance. The problem however, is that there is no simple measure of validity.

One way to establish validity would be to examine learner assessments on chemistry projects over an extended period using an educator who is recognized as an expert in the field. One could then create a rank order of learner capability. Thereafter, one would administer the activity to these same learners, assess the work and create another rank order. If the activity is a valid measure, then these two rank orders ought to correlate well. For many reasons, this means of establishing validity was not available to us and we therefore developed a different approach, based on the judgment of an expert panel. Given a set of experts in the field of chemistry education, it is reasonable to ask whether they believe that the activity represents what they regard as an authentic chemistry task. This is referred to as face validity.

6. SAMPLE

The selection of the sample of learners followed a proportional stratified random procedure based on schools. It was estimated that a sample of 400 learners is required in order to ensure adequate power of the analyses and generalizability to the population of 4000 learners (40 learners in each 20 schools). This sample comprised the treatment group of learners who have experienced the chemistry programme to various extends in grades 11 and 12. The control group is of equipment size and distribution as illustrated in table 2.

<table>
<thead>
<tr>
<th>ESTIMATED EVALUATION GROUPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>11</td>
</tr>
<tr>
<td>12</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Table 2. Proposed sample groups
7. DESCRIPTION OF THE SAMPLE

A total of 800 learners were finally involved in the collection of quantitative data. This sample is described in the following tables in terms of the variables of treatment (Table 3), gender (Table 4) and grade (Table 5). The sample utilized was very similar to that proposed in order to ensure valid generalization to the population.

<table>
<thead>
<tr>
<th>TREATMENT</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>354</td>
<td>49</td>
</tr>
<tr>
<td>Non-treatment</td>
<td>372</td>
<td>51</td>
</tr>
<tr>
<td>Total</td>
<td>726</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 3. Sample divided into treatment and non-treatment groups

<table>
<thead>
<tr>
<th>GENDER</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>356</td>
<td>49</td>
</tr>
<tr>
<td>Female</td>
<td>348</td>
<td>48</td>
</tr>
<tr>
<td>Incomplete returns</td>
<td>22</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>726</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 4. Sample divided by gender

<table>
<thead>
<tr>
<th>Grade</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>367</td>
<td>51</td>
</tr>
<tr>
<td>12</td>
<td>336</td>
<td>46</td>
</tr>
<tr>
<td>Incomplete returns</td>
<td>23</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>726</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 5. Sample divided into grades

8. QUALITITATIVE FINDINGS AND DISCUSSION

The impression gained from talking to a broad range of people involved in the project is that it is received positively and it is beneficial. Very few voices of dissent were registered as far as the value of the project is concerned. The attitude toward the future of the project is generally optimistic, but not without concern in a number of areas. The following data describes the findings from interviews and discussion with the qualitative sample.
Project level and content

The project materials are well structured and the modules well organized. A quite specific need has been satisfied by the project and materials, but eventually (around 2007). These will no longer be appropriate. Prior to 2006, the materials will need to be evaluated and some redesign takes place in order to match them with the developing national curriculum. The links between the project and the curriculum need to be fostered well before them in order to maximize the experiences gained through the project, and maximize the experiences gained through the project, and in order to ensure the flow-on of its continued benefits.

Subject Advisors

The subject advisors generated an effective enthusiasm for chemistry education. As fieldworkers their responsibilities have moved to more educator and school support. They recommend the student lab as a teaching strategy as it helps learners to develop the necessary skills, knowledge and values as stipulated in the Assessment Standards for Physical Science.

Concerning the dissemination of teacher experience, all the subject advisors to whom we spoke recognized the scale of the task of training educators in order to disseminate the chemistry student lab programme more widely. The following comments were commonly voiced:

- Satellite schools could be grouped around experienced schools
- Pilot schools could run workshops - a cascade model
- We could video some lessons and send them to other schools

8.3 Project educators

Concerning the training of educators, they commented that the training was highly effective in helping them to completely transform their approach to teaching and learning. This pedagogic transformation was attested to by almost every educator in the project.

Concerning the pedagogy underpinning the programme, it has been the active, problem solving pedagogy, that educators have been trained to use. There are several elements comprising support for this new pedagogy:

- It makes learning easy and enjoyable
  - It is easier to learn because you have practical and theory put into practice
  - Enjoy the teaching styles and interactive learning
  - There is fun

In attempting to solicit from educators what they believe were the important issues regarding resources, the majority are of the view that the resources were not sufficient.
Knowing how expensive and attractive chemistry resources are, security of facilities was seen as very important.

The benefits of the programme to educators are universally agreed by the subject advisors and the educators themselves. Stated simply it is that the programme has enriched and empowered them – as individuals and as professionals:

- The opportunity to grow
- The educator is very much enriched
- It has boosted their morale
- I am more skilful now – I don’t match – I do

These benefits to the educator centre in their classroom practice, but over spill into their personal view of themselves as professionals throughout the school.

9. QUANTITATIVE FINDINGS

The scores are averages across the whole sample and are on a scale 1-4.

<table>
<thead>
<tr>
<th></th>
<th>Project</th>
<th>non project</th>
<th>difference</th>
<th>t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holistic</td>
<td>2.53</td>
<td>2.18</td>
<td>0.35</td>
<td>0.03</td>
</tr>
<tr>
<td>Project sample</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>year 11</td>
<td>2.59</td>
<td>2.48</td>
<td>-0.11</td>
<td>0.63</td>
</tr>
<tr>
<td>Non project sample</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>year 11</td>
<td>2.27</td>
<td>2.10</td>
<td>-0.17</td>
<td>0.43</td>
</tr>
</tbody>
</table>

10. SUMMARY

In summary, the project has been successful in most aspects and is a model of education / industry partnerships. North West University (NWU) is to be applauded for their foresight in establishing this programme in 2003. The verification for the need of such programmes in South Africa has only increased since then.

There are significant quantitative advantages to learners in studying chemistry through the NWU modules. Project material should continue to be developed with consideration given to the directions as indicated in the national curriculum, and the project should be more widely implemented within the province.

The management of the project should be transferred to the provincial department of education. The project model should be used in the development of chemistry education resources for primary and middle school educators.
References


Physics students’ experiences of force and algebraic signs in 1-dimensional motion in mechanics

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Abstract
Physics students’ of experiences of positive (+) and negative (−) algebraic signs as applied to forces in 1-dimensional motion in mechanics was explored using three everyday experience contexts in physics. The students were interviewed about their conceptual understandings of algebraic signs as applied to high school physics notions of forces. The interviews were analysed from a phenomenographic perspective. Four different conceptions and hierarchical relations of the different ways that students’ conceptualize algebraic signs for force were identified. The data highlights the need for educators to take cognisance of the various but limited conceptualizations of force and its associated algebraic signs in 1-dimensional motion in mechanics.

Introduction
In this study of motion-mechanics the symbolic representations of algebraic operations and subsequent manipulation and interpretation of those symbols within the context of problem solving in one is focussed. Sign convention is an arbitrary choice of mathematical representation used as a technique in problem solving, for example, algebraic signs (+) and (−) is used to denote direction of motion of object and are referred by Roth, Tobin and Shaw (1997) to as “inscriptions - numbers, graphs, signs, symbols” (p. 1075). However, research has shown that students studying school and tertiary physics are often confused...
by the application of algebraic signs, particularly in vector-kinematics and dynamics (Govender, 2007), Rebmann & Viennot, 1994). In this regard, Rebmann and Viennot (1994) argue that since algebraic language is one of the main tools used in physics, it is educationally beneficial to analyse students’ comprehension of and skill in algebraic procedures including their notion of algebraic signs. Since physics teachers play an important role in the development of their students’ conceptualization of fundamental concepts, of which the concept of force is significant, it is critical to develop insight into the different ways in which students’ understand algebraic signs associated with forces in 1-dimensional motion in mechanics. A literature review of work in this area of physics has shown that while studies of teacher and students notions of forces, gravity and motion (Gunstone & White, 1981; D. Palmer, 2001) have been exhaustive, research related to algebraic signs associated with the concept force in mechanics have not been researched. This study attempts to contribute to filling this gap by exploring the different ways that students’ conceptualise algebraic signs associated with forces in 1-dimensional motion in mechanics.

Since the study was about identifying the range of conceptions of assigning algebraic signs for force in mechanics, Phenomenography as a research perspective chosen as an appropriate method to analyse students’ different conceptualizations. Phenomenography was developed by Ference Marton (Marton & Booth, 1997) to discover the qualitatively different ways in which people experience, perceive, and conceptualize various aspects of, and phenomena in, the world around them. In this study, the phenomenon is positive (+) and negative (−) algebraic signs as applied to the concept of force in mechanics was explored. The research question explored was “What are preservice physics students conceptions of algebraic signs related to forces in 1-dimensional mechanics?”

Literature Review

Sign convention in physics

In physics, a sign convention is a choice of the signs (plus or minus) of a set of quantities, in a case where the choice of sign is arbitrary - meaning that the same physical system can be correctly described using different choices for the signs, as long as one set of definitions is used consistently. Thus central to a thorough experience of sign
conventions is the notion of arbitrariness or free choice of assigning signs is comprehended. Using sign convention such as positive (+) and negative (–) algebraic signs performs an essential role in physics, as it provides us with a succinct and efficient method for use in solving problems especially in mechanics. Rebmann and Viennot (1994) investigated university students’ difficulty in relating the motion of an object to its variables and algebraic formalism. In an investigation with physics students in mechanics to determine correspondence between mastery of algebraic sign use in physics and added that correct usage and conventions are far from obvious to physics students. Lawson and McDermott (1987, p. 811) also found that students teacher make little connection between the algebraic symbols of the formula and the features of the demonstration – unlike a physicist, who almost ‘sees’ the application of formula to real world situations. Students experience confusion surrounding how algebraic signs are to be assigned especially in the transition between one- and two-dimensional motion, with the notion of scalars and vectors adding to their complexities. (Allie & Buffler, 1998) noted that where vectors are labelled with positive and negative signs, “high-school students end up perceiving no practical difference between scalar and vector algebra” (p. 618). Scalars have a sign and a magnitude whereas vectors have magnitude, which is inherently positive, and has direction (Warren, 1979).

Research on Force Conceptions

The Mechanics Baseline Test by Hestenes and Wells (1992) reported that the poor scores were generated by questions requiring an understanding of force. Hestenes and Wells (1992) adds that while students face an immediate hurdle with the concept of force, inabilities to reason correctly about vector quantities is also a hurdle. First-year university and final year high school physics students’ conceptualizations of fundamental concepts in force has been explored using the phenomenographic research perspective (Dall’Alba et al., 1993; Govender, 1999). From the analysis of the interviews from these studies, a hierarchical set of conceptions of the different ways students and students conceptualize the concepts in mechanics have been developed and the relationship between different levels of understandings have been identified.

The above literature review suggests that the conceptualization of algebraic signs and
force concepts in dynamics can be a complex issue. As no studies were published on algebraic signs related to force in mechanics, possibly be due a notion by physicists that there is little or no difficulty experienced by first-year students.

Methodology

The Phenomenographic Approach

In this study students seek to recognise and structure relationships of the real world of 1-dimensional motion, and attempt to link the real world phenomena with physics concepts and definition which they were formally presented with in class. Deep knowledge of the ways in which students conceptualize significant phenomena and concepts within a domain prior to study, is believed to be critical for developing their understandings of such phenomena, and, hence, lead to the mastery of the domain (Bowden et al., 1992). This study uses the phenomenographic research approach to analyse the data. The phenomenographic was developed by Ference Marton (1981) to discover the “qualitatively different ways in which people experience, conceptualise, perceive and conceptualize various aspects of, and phenomena in, the world around them”. According to Marton and Booth (1997), phenomenography uncovers not the ‘inner world’ of the students but how the students see his or her relation to the world. Thus phenomenography is a valid methodology to identify the distinctive different ways in which students organise their relations and understandings of scientific phenomena to the world. In all phenomenographic studies and in particular phenomenographic studies in physics (Dall'Alba et al., 1993; Linder & Erickson, 1989), it has been found that each phenomenon, concept or principle can be understood in a limited number of qualitatively different ways. In this study, it is also assumed that a limited number of ways of conceptualizing positive (+) and negative (−) algebraic signs as applied to forces in 1-dimensional motion physics can be found.

Design of Study

This study formed part of a longitudinal qualitative case study. The study involved interviewing 19 first-year physics students in order to determine their conceptualisations of positive (+) and negative (−) algebraic signs associated with the concept in force in 1-
dimensional motion in mechanics. The students were prospective physics teachers pre-selected for a four-year teacher-training course. An interview protocol was used to facilitate the elicitation and collection of students’ conceptualizations of algebraic signs and their notion of forces. The students interviews were carried out on an individual basis and were based on three demonstrations that they likely to have encountered in everyday life. The first was ‘an object rolled on a smooth surface’, the second was ‘an object thrown up and returning to its original position’ and the third ‘an object rolled up an inclined plane and returned to its original position’. In all these situations the students were required to discuss how positive (+) and negative (−) algebraic signs is assigned to the concept of force in 1-dimensional motion in mechanics.

Analysis of Data
The transcripts that originated from different individual interviews made up the data to be analysed. The data was then analysed via the phenomenographic analysis. Initially, the process involved looking for comprehensive structures of use and explanation of algebraic signs in all the data and, then identifying distinct ways of conceptualising positive (+) and negative (−) algebraic sign convention associated with forces in 1-dimensional motion. Different conceptualizations of forces associated with signs for 1-dimesional motion and not the teachers were being sampled. There was no attempt to fit the data into predetermined categories. The categories of conceptions of algebraic signs for forces drawn from the interview data were obtained from a lengthy process of iteration. To ensure reliability of data, the process of iteration was repeated several times until a stable set of categories emerged. To ensure validity of data, the ‘cut-out’ slips of interview data was re-worked together with a physicist with experience in phenomenography, ensuring that the categories of conceptions were consistent to the ones obtained by the researcher. The final result is expressed as an outcome space that is defined as “the pool of meaning, a complex of categories of description comprising distinct groupings of aspects of the phenomenon and the relationships between them” (Marton & Booth, 1997, p. 125). The analytic sketch of the process was developed for the reader to be aware and to appreciate how the categories of description and their characterizations as ways of experiencing were obtained. The example descriptions that
follow (Table 1) only represent contributory examples from all the descriptions gathered from the interview protocol.

**Results of study**

Table 1 provides a general description of categories of conceptions with examples to elucidate how students assigned algebraic signs to forces in 1-dimensional motion. The conceptions captured are all possible ways of assigning algebraic signs for forces in 1-dimensional motion in mechanics for an object: pushed horizontally on a smooth surface, pushed on an incline plane and thrown up.

Table 1: Categories of conception for positive (+) and negative (–) algebraic signs applied to forces in 1-dimensional motion in dynamics.

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<td>The students says that there is an upward force (+) sign exerted by the hand on the ball while it is in the air. The force of gravity acts downwards (-) sign.</td>
<td>The force exerted on the ball by the hand is assigned a positive (+) sign while the ball is in the air. The frictional force is assigned a positive (+) sign because it is a strong force or a negative (-) sign because it cancels the upward force.</td>
<td>Three forces act on the object while it is in the air and each is allocated a sign. The force of gravity is given a negative sign and frictional force a positive sign because it is a strong force. The applied force which acts upwards in the direction of motion of the object is allocated a positive sign.</td>
<td>Force of gravity acts downwards, negative (-) sign. Friction acts in all directions, not sure of signs (for falling bodies).</td>
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We observe from Table 1 that there are four variation in ways in which students’ conceptualize algebraic signs assigned to forces in the case of falling bodies and incline plane demonstrations.

**Examples and analysis of interviews supporting the categories of conceptions**

The discussion to follow examines in detail the variation in ways the students understand
algebraic signs in mechanics as revealed from interviews conducted during the demonstrations and as evident in Table 1. Each category of conception is supported by sample evidence obtained from their interviews. The main purpose of matching interview extracts with categories of conceptions was to provide strong evidence linking fieldwork, that is, students' conceptions from interviews of the phenomenon of algebraic sign convention, with the invention of categories of conception (Table 1).

A. Algebraic signs are arbitrarily assigned relative to the directions of motion and force exerted on the object.

Interviewer: Would you assign any algebraic signs for forces?

Student: Yes. Positive for your upward applied force and negative when the ball goes
down due to gravity.

The student displays the ‘motion implies force’ concept commonly identified misconception in literature (Halloun & Hestenes, 1985). It seems that since there are two directions of motion selected, up and down, the student also selects two forces acting on the ball in both these directions: an upward force (+ sign) exerted by the hand on the ball while it is in the air and the force of gravity acting downwards (- sign). He/she does not discern that situation at the point of application of the force exerted by the hand on the ball is different with the situation of only the ball in the air, where there is no external force of the hand but only gravitational force acting downwards. This view corresponds to common notion of an ‘impetus force’. This is interpreted as when an object is thrown, the “active agent imparts to the object a certain immaterial motive power which sustains the body’s motion until it has been dissipated due to resistance by the medium” (Halloun & Hestenes, 1985, p. 1057). In the conception A, the active agent is assigned a positive (+) sign to the external force (incorrect force conception) and the force of gravity, considered as the resistive force is assigned a negative sign (correct sign assigned and
Here algebraic sign is correctly assigned to the displacement of the object. Displacement as a vector quantity is assigned signs which are denoted by direction in the case of 1-dimensional motion. The students’ link force with vectors as vectors can be assigned algebraic signs. The student is also aware of the arbitrary nature of sign convention and that any direction of motion can be assigned a + or – sign as long as one is consistent.

B. Algebraic signs for the applied force are positive and opposing air frictional force is assigned positive or negative sign.

    Interviewer: How would you bring in sign conventions in terms of forces?
    Student: Frictional will be positive.
    Interviewer: Why?
    Student: Because we always worked with positive value for friction force.
    Interviewer: What does it mean when you say its’ positive?
    Student: the force that’s acting on it .. is like a strong force acting.

The students’ displays the motion implies force concept. The applied force stills acts on the ball while it is in the air but the frictional forces act to slow down the ball instead of the force of gravity (as mentioned by students in the category above).

While the force exerted on the ball by the hand is positive (+), two ways of experiencing sign conventions for friction are chosen by the students. Firstly, frictional force is positive (+) because it is a strong force. Secondly, it is negative (-) because it opposes the motion and cancels the upward force. In both cases the frictional force acts downwards but two different sign conventions are allocated for different reasons

C. Algebraic signs are assigned for frictional force a positive sign because it is a strong force and the force of gravity is assigned a negative sign.

    Interviewer: How would you discuss sign conventions for forces?
Student: Yes, the force of gravity will be negative. Frictional will be positive. Upward
force is positive.

Interviewer: Why?
Student: Because we always worked with positive value for friction force.

Interviewer: What does it mean when you say it’s positive?
Student: The force that’s acting on it … is like a strong force acting.

The student consider a system where three forces acting simultaneously on the object while it is in the air and each force is allocated a sign. The force of gravity is given a negative sign because the ball is attracted downward to the earth and frictional force a positive sign because it is a strong force. This also acts downwards to oppose the upward motion. The applied force on the object acts upwards in the direction of motion of the object and is given a positive sign. The motion implies force concept applies incorrectly here as well. The teachers’ way of conceptualizing force can be compared to the earlier views of scientists, for example, Albert of Saxony who explained projectile motion as involving a “compromise between the effects of impetus, gravity, and air resistance” (Halloun & Hestenes 1985, p. 1058). The students use scalar and vector concepts inappropriately to demonstrate this compromise - scalar addition is used in the case of strong, opposing, frictional forces and vector concept of direction is used for gravitational and forces applied by the hand.

D. Algebraic signs are uncertain for air friction as it acts in all directions and not assigned for both falling body and incline plane.

Student: Signs… gravity will be negative because it is acting downwards. I took upwards as positive and air friction, I don't know what sign that has.

Interviewer: In which direction does it act?
Student: I think it acts in all directions.

The students’ conceptualization of the force of gravity is that it acts downwards and assigns a negative (-) sign which is an appropriate conception. For friction, the students
states that it acts in all directions and is not sure of sign conventions in the case of falling bodies. This inappropriate conception for the sign of friction could possibly arise from the notion that air molecules move in all directions. Since air friction arises from motion of air molecules and air molecules move in all directions and possibly from students’ conception of Brownian motion, air friction acts in all directions when the ball is thrown. The conflict arises when sign convention has to be allocated for friction and to resolve this, the students say that either no signs allocated or there is uncertainty about the sign for friction. The question of what direction can you give to molecules that are moving randomly in all directions? must probably be uppermost in the teachers’ thoughts. No signs for friction are assigned in the case of incline plane.

Discussion

In this study, the students reveal several inappropriate understandings with assigning algebraic signs and this understanding is compounded by their notions of poor force concepts in mechanics. They inappropriately assign an algebraic sign for force that was removed from the object at the point of release. This implies an erroneous notion of force, namely, motion implies force exists, as serious concern ad these are potential physics teachers. The natural or naive motion implies force concept is prevalent for a wide range of ages from primary to high school (Palmer & Flanagan, 1998; Trumper & Gorsky, 1996; Twigger et al., 1994).

When an object was released on a rough horizontal surface or in the air, the frictional force was given a negative sign because it was acting in the opposite direction to the motion of the object. The concept of air pressure which is exerted in all directions and air friction was viewed as synonymous and the direction of assigning an algebraic sign to frictional force was problematic for the students as they thought that no direction could be associated with air friction. However, conception B (see Table 1) indicates that students are aware that the algebraic signs are reversed for air friction acting on the body thrown up and coming down. If the object is thrown up, and upward direction of motion (displacement) is taken to be positive, the force of gravity and the force of air friction (which opposes the motion of the object) which is acting downwards is now assigned a negative sign. If the object is coming down, the force of gravity is still acting downwards, hence a negative sign but the air resistance act upwards to slow down the ball, hence a
positive sign. In the category of description D, the allocation of signs for forces acting on
the ball in both falling body and incline plane depend on their concept of friction and on
their notions of algebraic signs for vectors in 1 dimensional motion.

Two different notions of assigning signs in the case of frictional force (see B and D
in Table 1) suggesting that the plane of motion in the demonstrations may be an
important factor in assigning signs for frictional forces. A study by Twigger et al., (1994)
confirms a similar view. They had conducted a study to identify features of the students'
reasoning about horizontal and vertical motion with 36 students aged 10-15. They
concluded that besides the erroneous conceptions of force reported in the literature,
reasoning about vertical motion differed from horizontal motion and there was little
evidence for any change with age in the conceptions used to explain motion.

It is surprising that not one of the categories of description from Table 1 contained
the appropriate way of conceptualizing algebraic signs for forces for 1-dimensional
motion suggesting the compound difficulty of conceptual understanding of dynamic
concepts (Reif & Allen, 1992) and algebraic signs. For one-dimensional motion (as a
special case), algebraic signs assigned to forces is given by initial vector directions
chosen for up and down or left or right.

Conclusion

Phenomenographic analysis of this study (see Table 1) has revealed four different ways
of conceptualizing algebraic signs with regard to forces for 1-dimensional motion in
dynamics. Table 1 reveals that algebraic signs are conceptualized in terms of direction
and magnitude. The study reveals that the preservice teachers as physics students assign
algebraic signs inappropriately to forces and do not hold a holistic and a consistent model
of algebraic signs and sign convention with regard to forces and mechanics in general.
The study also reveals that erroneous conception of forces in 1-dimensional motion
impedes their understanding of algebraic signs and hence may limit their ability of solve
problems in physics.

Implications for Teaching

This study suggests that algebraic signs as an aspect of sign convention and concepts in
force which are central to physics teachers’ scientific conceptualizing in a wide range of
topics should be analysed more in-depth and be given an appropriate amount of teaching
time and maybe enhanced using computer simulations (Doerra, 1997; Testa, Monroy, &
Sassi, 2002). This can be achieved by first exploring students’ general notions of
algebraic signs and sign conventions, alternative conceptions of algebraic signs in vector-
kine kinematics and dynamics and then, by engaging students’ perceptions, using the outcome
space for algebraic signs for 1-dimensional motion for forces invented in this study (see
Table 1).

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377


