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Making Mathematics, Science and Technology Education,
Socially and Culturally relevant in Africa

Proceedings Editors M. Ogunniyi, O. Amosun, K. Langenhoven,
S.Kwofie, S. Dinie

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MESSAGE FROM THE PRESIDENT

It is a great pleasure to welcome you all to the 21st annual SAARMSTE Conference held at the University of the Western Cape. As our 21st birthday, this is an especially significant conference as it marks the successful development of our community to continually mature to this important age. Twenty-one years is indeed a significant milestone and we will be celebrating this milestone at the conference Gala event in the beautiful Kirstenbosch Botanical Gardens. Organising a SAARMSTE conference is an enormous responsibility and takes a large amount of commitment and work and I would like to thank the members of the LOC and many others who have given so generously of their time to organise this event.

I would also like to thank the University of the Western Cape for hosting this conference. The SAARMSTE conference is a key event in the annual calendar of SAARMSTE as it is the largest gathering of our members and as such provides us with a wonderful platform for sharing, learning and networking. We are a strong and growing community and I thank all our members for their on-going participation in our conferences and other SAARMSTE activities.

Our conference theme this year is, “Making Mathematics, Science and Technology Education, Socially and Culturally relevant in Africa.” Given the dominant crisis discourse that pervades in relation to Mathematics and Science Education in Africa this theme is critical. The theme calls on each of us to find ways to contribute to finding a way forward to the many challenges that face our continent in addressing the challenges of mathematics, science and technology education. Our conferences are a critical point where we stimulate engagement, discussion, debate, learning, leadership and action. Thank you to all of you for your ongoing commitment to SAARMSTE and to the imperative that as members of SAARMSTE we contribute positively to finding ‘relevant’ pathways of progress in this field.

Finally, I wish 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.

Enjoy the conference!

Mellony Graven
SAARMSTE President
January 2013
Review policy of SARMSTE 2013 Conference Papers
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The purpose of reviewing is to provide constructive comments from other researchers in an effort to promote high-quality papers and presentations. At least two reviewers will look at each long paper and extended abstract. Authors will be required to consider their comments and may be asked to revise their work before submitting their final paper. The review process is “blind” both ways, names of authors and reviewers are not revealed to each other, although reviewers can choose to reveal their names to authors in the interests of further discussion. It is SAARMSTE policy to use the journal reviewers as conference reviewers.

FOREWORD
This SAARMSTE 2013 Conference celebrates the 21st Annual Meeting to be held at the University of the Western Cape. In one sense it is a birthday celebration of Mathematics, Science and Technology Education (MSTE) Research in Africa.

New researchers are particularly welcome. All stages of education are included, and the papers presented cover Early Childhood Development, Foundation Phase, General Education and Training, Further Education and Training and Higher Education and Training levels.

This annual conference maintains its regional, national and international flavour in a way that contributes to the spirit of Ubuntu in Africa and further afield. Researchers add their exploratory voice to the value and relevance that the social and cultural fabric of African society also holds for education.

While looking for connections across subjects and research areas, we also hope to build on strands in previous conferences. As we stand on the threshold of change in our global society, social networks have speeded up access to knowledge on a large scale and presents MST education with challenging perspectives in areas requiring relevant curriculum policies and research. The contributions by MSTE researchers are encouraging pointers to support mechanisms for MST teaching and learning that occur in a social and cultural context and ultimately stimulating knowledge production on the African continent. The Local Organising Committee welcomes you to a vibrant experience both academically, professionally and socially. The community spirit of SAARMSTE and its visionary mission is a vital support base for successful MSTE through these research initiatives and outcomes.

It is with heartfelt appreciation that I want to thank all the members of the Local Organizing Committee, staff of the School of Science and Mathematics Education at UWC, our external reviewers, the SAARMSTE Executive, our former Director, Meshach Ogunniyi of the Faculty of Education, the Dean of the Faculty of Education and the UWC Executive.

Keith Roy Langenhoven

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ACKNOWLEDGEMENTS

We are immensely grateful to the following sponsors for their generosity and valued support for this 21st celebration of SAAEMSTE’s annual conference:

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### TABLE OF CONTENTS

**SAARMSTE COMMITTEES** ........................................................................................................... ii

**LIST OF LONG PAPER REVIEWERS** .......................................................................................... iii

**MESSAGE FROM THE PRESIDENT** ............................................................................................ iv

**21ST SAARMSTE ANNUAL CONFERENCE PAPERS** ................................................................. v

**MATHEMATICS EDUCATION** .................................................................................................... 2

- Students’ beliefs and attitudes towards mathematics in Mozambique: Influence of parents, economic resources, and cultural factors .................................................. 3
  - Adelino Evaristo Murimo & Helen J. Forgasz ........................................................................... 3

- Relevance and school mathematics .............................................................................................. 14
  - Mercy Kazima ........................................................................................................................... 14

- Designing a PCK framework for the professional development of statistics teachers .................. 29
  - A. Makina ............................................................................................................................... 29

- Teachers’ reflections on nonstandard students’ work ................................................................. 44
  - Arne Jakobsen¹ & C. Miguel Ribeiro² ................................................................................... 44

- Procedural spectrums: translating qualitative data into visual summaries ............................... 55
  - Debbie Stott¹, Mellony Graven² ......................................................................................... 55

- Teachers’ perceptions of factors that contribute towards their effective practice: what the data tell us ................................................................................................................ 67
  - G. H. Stephanus¹ & M. Schafer² .......................................................................................... 67

- Students’ conceptualizations of 3-variable functions and the role of visualization in the learning of multivariate calculus ................................................................. 79
  - Jonatan Muzangwa ................................................................................................................ 79

- Pedagogic strategies used by educators who do not speak the learners’ main/home language for proficient teaching of functions in multilingual mathematics classrooms ........................................................... 89
  - Lydia Mutara¹ and Anthony A. Essien² ................................................................................ 89

- Tensions in the transition from informal to formal geometry .................................................... 101
  - Lynn Bowie ............................................................................................................................. 101

- Dimensions of learning as identity: A demonstration from culturally-based lessons in grade 9 mathematics ................................................................................................. 116
  - Madusise, Sylvia & Mwakapenda, Willy .............................................................................. 116

- The intended and the implemented: one task in a GeoGebra context .................................... 132
  - Margot Berger ....................................................................................................................... 132

- An Assessment of theory of computation in computer science curricula ............................. 145
  - C. M. Keet ............................................................................................................................. 145
Integrating visual and analytical strategies: An analysis of grade 11 learners’ problem solving approaches to a reflective symmetry task........................................ 157
  Michael Kainose Mhloko ........................................................................................................ 157

How did pupils solve number brick after lessons of substantial learning environment in Central Province, Zambia?.................................................. 169
  Nagisa Nakawa ......................................................................................................................... 169

On the constituents of Primary Maths Teacher Identity: Towards a model .......... 184
  Pausigere Peter1 & Graven Mellony2 ......................................................................................... 184

Operationalizing Wenger’s three modes of belonging in the context of a mathematics teacher enrichment programme ................................................ 197
  Nyameka Kanga1, Michael Kainose Mhlo2 & Marc Schafer3 .................................................. 197

An examination of pupil difficulties in solving geometry problems..................... 208
  Roger MacKay .......................................................................................................................... 208

SCIENCE & TECHNOLOGY EDUCATION............................................................................ 219

Making computer applications technology educators’ adaptation to changes relevant in South Africa ................................................................. 220
  Leila Goosen1 & Marli Breedt2 ............................................................................................... 220

Effects of dialogical argumentation instruction in a computer-assisted learning environment on grade 10 learners’ understanding of concepts of chemical equations........................................................................................................ 231
  Frikkie George1 & M Ogunniyi2 ............................................................................................. 231

Making educators’ use of virtual learning environment tools relevant for open distance learning across Africa ................................................................. 246
  Leila Goosen1 & Lizelle Naidoo2 ............................................................................................. 246

Comparative effects of two and three dimensional methods of graphics in autocad on interest of national diploma students in engineering graphics ............. 257
  J. A. Jimoh ................................................................................................................................ 257

Teachers’ views on the integration of science and indigenous knowledge systems in the South African school curriculum: The debate continues.............. 274
  Keith Langenhoven1 & Ruth Stone2 ......................................................................................... 274

Teaching thinking, study, investigative and problem solving skills in biology: A case of curriculum implementation in Zomba schools.............................. 291
  Nellie M Mbano ..................................................................................................................... 291

An evidence-based findings of the effects of active teaching and learning methods on a large and under-resourced primary school science class.................. 303
  Andrews Nchessie1; Dorothy Nampota2 & Mercy Kazima3 ................................................... 303

Exploring Effects of Argumentation Instruction Model on Science-IKS Curriculum in Teacher Education............................................................. 318
  Simasiku Siseho1, Daniel Angaama2 & Meshach Ogunniyi3 .................................................. 318

Mapping sustainability and science education............................................................... 330
  Allyson Macdonald .................................................................................................................. 330
Conceptual, attitudinal and practical change concerning science and indigenous knowledge integration using argumentation ................................................................. 348
Olufunmilayo l. Amosun; Meshach B. Ogunniyi2; Alvin Riffel3 ....................................................... 348

The effects of a science-IKS program on participating educators’ views regarding the implementation of an integrated Science-IK curriculum in South-Africa..... 363
Dinie, S1, February, P2, & Kroukamp, G3 ......................................................................................... 363

The Integration of ICTs in the teaching and learning of mathematics, science and technology subjects in Swaziland secondary schools ________________________ 376
Ntombenhle Dlamini1, Michael Mhlungu2, Linda Simelane3, Musa Hlophe4, Themebelihle Dlamini5, ................................................................................................. 376

Validating an instrument for use in assessing the technological literacy of upper secondary school students.............................................................. 391
Melanie B Luckay & Brandon l Collier-Reed .................................................................................. 391

The status of technological literacy and awareness among learners.................. 402
Moses Makgato .................................................................................................................................. 402

Challenges facing FET teachers in the implementation of technology in the further education and training band in North West .................................................. 411
Keorapetse N. Marumo .................................................................................................................. 411

Exploring the nature of knowledge building amongst teachers using the argumentation instructional strategy: Reflections from a community of practice .................................................. 423
Duncan Mhakure1; Ngonidzashe Mushaikwa2 & Lynn Goodman3 .............................................. 423

A case study using dialogical argumentation to explore grade 10 learners’ scientific and indigenous beliefs about lightning.............................................. 435
Partson Virira Moyo & Meshach B. Ogunniyi ................................................................................. 435

Teachers’ and teacher trainers’ reflexivity and perceptual shifts in an argumentation-driven indigenized science curriculum project ......................... 446
Meschach Ogunniyi ....................................................................................................................... 446

Knowledge production of indigenous technology: learners’ understanding of their context ................................................................................................. 457
Sylvia Manto Ramaligela .............................................................................................................. 457

Moving classroom practices beyond the positivist view of scientific knowledge construction ........................................................................................................... 468
Senait Ghebru1 & Meshach Ogunniyi2 ............................................................................................ 468

The challenge of training Eritrean and South African teachers to implement a culturally relevant science-IK curriculum ............................................ 479
Senait Ghebru1 & Meshach Ogunniyi2 ............................................................................................ 479

The role of Indigenous Knowledge Systems in enhancing grade 9 learners’ understanding of a Natural Science Education Curriculum: An survey in a Geography classroom in Cape Town, South Africa.................................................. 500
Alvin Daniel Riffel 1 Keith Langenhoven2 Meshash Ogunniyi3 ...................................................... 500

A model for Africanising higher education curriculum: A quest for educational relevance ........................................................................................................... 531
Mishack Thiza, Gumbo.................................................................................................................. 531

A diagnostic teacher practice framework for science teaching: a case of projectile motion .......................................................................................................................... 546

Awelani V. Mudu ¹ Fhatuwani J. Mundalamo ² Thomas D.T. Sedumedi³ .................................. 546

Exploring high school teachers’ conceptions of the nature of scientific inquiry: A Case study ........................................................................................................................................ 559

Washington T. Dudu.................................................................................................................................................. 559

Teaching Thinking, Study, Investigative and Problem Solving Skills in Biology: A case of curriculum implementation in Zomba schools......................................... 577

Nellie M Mbano.................................................................................................................................................. 577

A framework for Understanding and Reflecting on Students’ Knowledge Structures about Aqueous Acid-Base Solutions ......................................................... 589

Thomas. D.T. Sedumedi, .............................................................................................................................. 589

X
MATHEMATICS EDUCATION

(Long Papers)
Students’ beliefs and attitudes towards mathematics in Mozambique: 
Influence of parents, economic resources, and cultural factors

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Abstract
The findings reported in this article are part of a larger study that examined the influence of父母, economic resources, and cultural factors (e.g., gender, home language, geo-location, and siblings) on self-perceived achievement in mathematics and other school subjects (SPA), and perceived usefulness of mathematics (PUM). The study involved 300 grade 7 students, and 225 parents from five public schools (3 urban, 1 rural, and 1 remote) in the central Province of Sofala in Mozambique. Surveys and interviews were used to collect data. Both the girls and the boys believed mathematics was their worst school subject and physical education their best. Gender differences in SPA were noted only in regard to moral and civic education and favoured girls. Parents’ perceived achievement for their children was similar to that of students, but they viewed mathematics as less useful for their offspring than the students themselves. A trend to view mathematics as more useful for boys than for girls was also noted among students and parents. Parental education, geo-location, number of siblings, and possession of electricity, TV, and internet at home were the most salient predictors of students’ SPA and PUM. Implications of the findings for policy and practice are discussed with emphasis on the role of parents as socializing agents of children’s task choices and achievement.

Introduction
In many developed countries such as Australia, England, and USA, research on gender issues in mathematics education have a long tradition, and gender differences in favour of boys have been found in regard to achievement in problem solving, participation in non-compulsory high level mathematics courses and applied fields, and affective dimensions (see Tiedemann, 2002, for review). Over the years, several theoretical models accounting for gender differences in mathematics learning outcomes have been hypothesized (e.g., Baker & Jones, 1993; Eccles, Adler, & Futterman, 1983; Ethington, 1992; Fennema & Peterson, 1985; Leder, 1990; Reyers & Stanic, 1988), and a number of intervention programs to mitigate the problem have been implemented worldwide (see Leder, Forgasz, & Solar, 1996, for review). Although research literature on gender issues in mathematics education is rife and measures to reduce disparities are well documented, it is still not known why gender differences in mathematics education to disadvantage of girls persist in most African schools (Asimeng-Boahene, 2006; Saito, 2004, 2010).

The most relevant studies in primary mathematics education in Sub-Saharan Africa conducted by the Southern and Eastern Africa Consortium for Monitoring Education Quality [SACMEQ] reveal that gender differences in mathematics achievement in favour of boys at grade 6 persist in Mozambique as well as in many other African countries from the SACMEQ region (see Saito, 2004, 2010). Inspired by the latest SACMEQ report that acknowledges the decline of achievement in mathematics in Mozambique (Makuwa, 2010) and also indicates that gender disparities in favour of boys persist (Saito, 2010), this study was conducted in order to determine the impact of gender, parents, possession of economic
resources, and cultural factors on grade 7 students’ self-perceived achievement (SPA), and perceived usefulness of mathematics (PUM). The research questions addressed were:

1. Are there gender differences in grade 7 students’ self-perceived achievement, and perceived usefulness of mathematics?
2. How do students’ and parents’ perceptions of students’ achievement and usefulness of mathematics compare?
3. Which selected parental background variables, and cultural factors are the best predictors of students’ perceived achievement, and perceived usefulness of mathematics?
4. Which owned economic resources are statistically significant predictors of perceived achievement and perceived usefulness of mathematics?

Theoretical considerations
The affective domain in mathematics education

McLeod (1992) conceptualized the affective domain in mathematics education as including three components, namely, beliefs, attitudes, and emotions. Other scholars (e.g., DeBellis & Goldin, 1999) have also considered value, interest, and aspirations to be components of affect. Mathematical related beliefs are viewed as the individuals’ subjective knowledge (a) about mathematics, (b) about self, (c) about mathematics teaching, and (d) about the social context where mathematics learning takes place (McLeod, 1992). According to Aiken (1980), an attitude towards mathematics is the predisposition to respond favourably or unfavourably to mathematics tasks, and has three attributes: cognition (beliefs, knowledge), affect (emotion, motivation), and performance (behaviour, action).

Else-Quest, Hyde, and Hejmadi (2008) investigated affect in mathematics education in terms of emotional reactions that children and their parents experience during mathematics homework. These authors found that positive emotions (e.g., interest, joy, and pride) were associated with better performance, while negative emotions (e.g., anxiety, tension, and frustration) were related to poor performance. Grootenboer and Hemmings (2007), and Leder and Forgasz (2010) have focused their studies on beliefs and attitudes towards mathematics. Interest in the study of affect in mathematics education is due to its influence on cognitive processes that affect achievement and students’ willingness to engage in mathematics activities (Grootenboer & Hemmings, 2007). Also, the formation and development of positive affect, such as more functional beliefs and attitudes towards mathematics and mathematics learning, are desirable objectives of mathematics education (Aiken, 1974, Reyes, 1984). Consistent with this, the development of positive affect is a core component of mathematics curricula in many countries of the world (Mullis, Martin, & Foy, 2008). For example, the Ministry of Education (Ministério de Educação, 2008) addressed the following mathematical related affective goals for grade 6 and 7 students in Mozambique:

1. To appreciate and understand the value and place of mathematics in the world and its use in other subjects;
2. To be interested and to persist in the solution of difficult mathematics problems;
3. To be interested and to have positive attitudes towards learning mathematics;
4. To view mathematics as a useful working tool;
5. To view mathematics as part of our cultural roots;
6. To view mathematics as a tool that helps us to think clearly and to reason better;
7. To view mathematics as a subject that has universal properties; and
8. To view mathematics as intrinsically beautiful as a logical and formal construction.

Hence, these objectives indicate that the formation and development of students’ positive affect towards mathematics are valued in Mozambique. However, studies aimed at determining the extent to which these goals are reached are scarce and, consistent with Mullis et al. (2008), if affective factors are considered important to mathematics education they should be monitored constantly. In order to fill this research gap, self-perceived achievement (SPA), and perceived usefulness of mathematics (PUM) were examined among primary school students. It should be noted that SPA is related to academic self-concept that is defined as “the individual’s perception of self with respect to achievement in school” (Reyes, 1984, p. 559). Apart from SPA, the academic self-concept also includes motivation/affect (Marsh, Craven & Debus, 1999). PUM is defined as “students’ beliefs about the usefulness of mathematics currently and in relationship to their future education, vocation, or other activities” (Fennema & Sherman, 1976, p. 5). PUM is a multidimensional variable that includes interest, general utility, need for high achievement, and personal cost (Luttrell, Callen, & Allen, 2010). Hence, SPA and PUM are framed within the affective domain, and are important constructs because they influence course enrollment choices, and career plans (Simpkins, Davis-Kean, & Eccles, 2006).

Theoretical framework for the study
Leder’s model of gender differences in mathematics learning outcomes (Leder, 1990), and the model of parent socialization (Eccles, 2005) were used to identify variables of interest to this study. Leder (1990) postulated that gender differences in mathematics education are influenced by environmental and learner related factors. Environmental factors comprise external forces that surround the learner (e.g., society at large, home, and school). Learner related factors include the differential development of verbal and spatial abilities of females and males, and their beliefs system. Leder’s (1990) model was used to select variables for this study because it emphasizes factors that are modifiable (unstable) rather than innate (stable) characteristics of the learner. The model of parent socialization (Eccles, 2005) was developed out of the expectancy-value theory (Eccles et al., 1983) and indicates that parents influence their children’s achievement related behaviours “through their role as models, and through their roles as expectancy and value socializers” (p. 127). The model suggests that children imitate and adopt the behaviours of parents and significant others such as teachers. This means that if mothers exhibit more anxiety towards mathematics than fathers and they reveal these differential attitudes to their offspring, then daughters and sons will be more likely to develop different beliefs and attitudes towards mathematics. The model was used in this study because it stresses the role of parent education. It was thus viewed as having implications for education in Mozambique because total adult illiteracy rates, according to 2007 Census, were 40% in urban areas, and 80% in rural areas (Instituto Nacional de Estatistica, 2011).

Results and discussion
SPA and PUM were used as dependent variables (DVs). Gender differences on SPA were examined first. Independent groups t-tests were conducted to compare SPA mean scores for girls and boys using a p-value cut-off of .01 (Bonferroni adjustment). A more stringent p-value was used in order to prevent inflated type one errors (Pallant, 2009) as several separate tests were performed. Using a p-value smaller than .001, one sample t-tests were also
conducted in order to determine whether students’ SPA for mathematics differed from their SPA in other subjects because there were nine different subjects. The tenth subject (Artwork) was excluded from the study as some students did not have a teacher for this subject at the time of data collection. Students’ SPA mean scores, one sample t-test results, and independent groups t-test results are presented in Table 1.

Table 1. SPA mean scores, one sample t-test results, and independent groups t-test results by school subject (Boys: N = 134; Girls: N = 166).

<table>
<thead>
<tr>
<th>Subject</th>
<th>SPA Mean scores</th>
<th>Independent t-test results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
<td>Girls</td>
</tr>
<tr>
<td>Physical education</td>
<td>3.76 **</td>
<td>3.94 **</td>
</tr>
<tr>
<td>Music education</td>
<td>3.67 **</td>
<td>3.87 **</td>
</tr>
<tr>
<td>Portuguese</td>
<td>3.74 **</td>
<td>3.69 **</td>
</tr>
<tr>
<td>English</td>
<td>3.59 **</td>
<td>3.68 **</td>
</tr>
<tr>
<td>Visual education and technology</td>
<td>3.61 **</td>
<td>3.67 **</td>
</tr>
<tr>
<td>Natural sciences</td>
<td>3.44 **</td>
<td>3.64 **</td>
</tr>
<tr>
<td>Social sciences</td>
<td>3.31</td>
<td>3.39 **</td>
</tr>
<tr>
<td>Moral and civic education</td>
<td>3.27</td>
<td>3.57 **</td>
</tr>
<tr>
<td>Mathematics</td>
<td>3.17</td>
<td>3.16</td>
</tr>
</tbody>
</table>

Notes. Response format: 1 = Weak, 2 = Below average, 3 = Average, 4 = Good, 5 = Excellent. **SPA mean scores are statistically significantly higher than the SPA mean score for mathematics at \( p < .001 \) (Bonferroni adjustment).

As can be seen in Table 1, the lowest students’ SPA was in mathematics. For boys, the SPA for mathematics did not differ from the mean for social sciences, and moral and civic education, but it differed from the means of the other subjects (\( p < .001 \)). For girls, the SPA mean score for mathematics was lower than the SPA mean scores of all other subjects (\( p < .001 \)). Remarkably, both the boys and the girls believed physical education was their best subject. The students’ high SPA for physical education is likely to be influenced by the nature of the subject. That is, physical education is generally an outdoor activity and all children are capable of participating in some kind of sports, and assessment is generally qualitative rather than quantitative. Gender differences on SPA were noted only in regard to moral and civic education and favoured girls. Interestingly, the aim of this subject in primary schools in Mozambique is teaching children to:

“Reconhecer a importância do bom comportamento na família, na escolar, no meio public, respeitar as regras de hygiene pessoal e pública. Desenvolver o amor, o espírito patriótico e o orgulho pela sua patria” (Ministério de Educação, 2008, p. 348). [To recognize the importance of good behaviour in the family, school, and in the public place, and to respect the rules of personal and public hygiene. To develop love, patriotic spirit, and pride for their country].

To examine students’ PUM, the sum of scores on the 14 items was divided by 14 (the number of items) to facilitate interpretation of scores within the range 1-5. Then, an independent groups t-test was conducted to compare boys’ and girls’ PUM mean scores. However, no statistically significant gender difference was found at \( p < .05 \) level (Girls: N = 166; M = 3.61, SD = .57; Boys: N = 134; M = 3.71, SD = .53).
Independent groups t-tests for equality of means were also conducted to determine whether parents of sons perceived their children to be better, and whether they believed mathematics was more useful to them than parents of daughters. Parents’ perceptions about children’s achievements in mathematics were not influenced by the gender of the child (Parents of sons: N = 111, M = 3.15, SD = 3.15; Parents of daughters: N = 101, M = 3.04, SD = 1.1). Similarly, no statistically significant differences were found between the responses of parents of sons (N = 115, M = 3.52, SD = .30) and parents of daughters (N = 104, M = 3.46, SD = .28) in regard to PUM for their offspring. However, despite the differences not reaching statistical significance, boys and parents of boys were more likely to hold higher SPA and PUM than girls and parents of daughters.

In order to determine whether parents viewed mathematics as more useful for their children than the children themselves, a paired t-test was conducted on PUM mean scores for parents and children as two independent groups that completed the same items. It was found that the mean for parents (N = 225, M = 3.49, SD = .03) was highly statistically significantly lower than the mean for children (N = 225, M = 3.68, SD = .06), t (223) = 4.5, p <.001. This result may have reflected the differential experiences that parents had with mathematics and the current experiences that their children have. In fact, during interviews parents were asked whether mathematics is important for their children and why and whether mathematics is important to get a job. The majority of parents interviewed did not believe mathematics helps to get a job and did not associate mathematics with jobs. However, they believed mathematics is important because it helps to count things, to make calculations, to check accuracy of bills, payslips, to open capacity, to reason, and to improve memorization skills. Only one parent said mathematics helps to solve problems. Another parent said mathematics is important because it helps to understand other school subjects such as physics, and chemistry.

To identify models made up of parental background variables, and cultural factors that best predict SPA and PUM, a stepwise regression analysis was applied because it specifies multiple models in a single regression command, and lists the variables excluded for not meeting the selection criteria and the level of statistical significance (Coakes, Steed, & Ong, 2010). To do so, the independent variables gender, age, education of parent, occupation of parent, geo-location, number of siblings, language, and number of books were entered into the regression equation simultaneously, and the dependent variables SPA and PUM were entered separately. A summary of the stepwise regression statistics including the models that were statistically significant are presented in Table 2.

**Table 2.** Summary of stepwise statistics illustrating statistically significant predictor models for PUM.

<table>
<thead>
<tr>
<th>DV</th>
<th>Models</th>
<th>Predictor IVs</th>
<th>B</th>
<th>SE</th>
<th>β</th>
<th>t</th>
<th>p</th>
<th>R²</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUM</td>
<td>1</td>
<td>Age</td>
<td>.15</td>
<td>.03</td>
<td>.38</td>
<td>6.0</td>
<td>.000</td>
<td>.141</td>
<td>36.4</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Education</td>
<td>.05</td>
<td>.02</td>
<td>.19</td>
<td>3.1</td>
<td>.002</td>
<td>.177</td>
<td>23.6</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Age</td>
<td>.13</td>
<td>.03</td>
<td>.33</td>
<td>5.3</td>
<td>.000</td>
<td>.177</td>
<td>23.6</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Education</td>
<td>.04</td>
<td>.02</td>
<td>.17</td>
<td>2.7</td>
<td>.008</td>
<td>.202</td>
<td>18.4</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Geolocation</td>
<td>.13</td>
<td>.05</td>
<td>.17</td>
<td>2.7</td>
<td>.010</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SPA was excluded from the analysis as it was not predicted by any of the IVs examined. As can be seen in Table 2, in regard to PUM, four models were identified. Age of the child made a unique statistically significant contribution of 14% to the variability of PUM scores. When combined with education of parent, both explained 18% of the variation of PUM scores. However, the best predictor model of PUM scores was a model made up of age, education of parent, geo-location, and siblings and explained about 22% of the variability of PUM scores ($R^2 = .222$). After observing that these variables predicted PUM scores, to identify groups that differed from each other within IVs, one-way between groups ANOVAs were conducted with Tukey or Games-Howell post hoc comparisons as appropriate (Pallant, 2009). It was noted that the youngest participating children (age = 11 years: N = 45; M = 4.13, SD = .48), children with fewer than 3 siblings (N = 66, M = 3.66, SD = .56), children from urban schools (N = 188, M = 3.79, SD = .58), and children whose parents had university education or were at university at the time of data collection (N=34 , M = 4.04, SD = .56), had higher PUM mean scores than the other groups of children, and the differences were highly statistically significant ($p < .001$). To illustrate, students’ PUM mean scores by education of parent are presented in Figure 1.

<table>
<thead>
<tr>
<th>4</th>
<th>Age</th>
<th>.10</th>
<th>.03</th>
<th>.23</th>
<th>3.5</th>
<th>.000</th>
<th>.222</th>
<th>15.6</th>
<th>.000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Education</td>
<td>.04</td>
<td>.02</td>
<td>.18</td>
<td>2.9</td>
<td>.006</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Geolocation</td>
<td>.12</td>
<td>.05</td>
<td>.15</td>
<td>2.3</td>
<td>.016</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Siblings</td>
<td>.10</td>
<td>.04</td>
<td>.14</td>
<td>2.3</td>
<td>.017</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. PUM = Perceived usefulness of mathematics.
As can be seen in Figure 1, students’ PUM means tended to increase as the level of parental educational background increased. That is, children with more educated parents revealed higher PUM, and children whose parents had no schooling or had grade 1 to 5 reported the lowest PUM.

The independent variable ‘possession of economic resources’ was examined using two levels: Yes (child possesses the resource) and No (child does not possess the resource). To compare means between children who possess and those who do not possess selected economic resources on SPA and PUM, independent groups t-tests were performed with a Bonferroni adjusted to a cut-off of .01 to avoid type 1 errors resulting from repetition of tests (Pallant, 2009). SPA and PUM mean scores, frequencies, and independent groups t-test results (t and p values) are presented in table 3 by economic resource.

As can be seen in Table 3, children who owned electricity, TV, computer, internet, piped water, and had a school uniform had higher PUM scores. None of the selected economic resources had a statistically significant relationship with SPA scores. Despite the differences not reaching statistical significance, the trends in the SPA and PUM scores revealed that the ownership of economic resources is associated with higher means. Although one would expect the ownership of a calculator, a cell phone or textbooks to influence positively the level of SPA and PUM, this was not the case in this study.

Table 3. SPA and PUM mean scores, frequencies, and independent groups t-test results by economic resources.

<table>
<thead>
<tr>
<th>Economic resources</th>
<th>DVs</th>
<th>Possession</th>
<th>Independent tests</th>
<th>t-test results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yes Mean</td>
<td>No Mean</td>
<td>t</td>
</tr>
<tr>
<td>Electricity</td>
<td>SPA</td>
<td>210 3.22</td>
<td>90 3.02</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PUM</td>
<td>208 3.76</td>
<td>90 3.42</td>
<td>5.0</td>
</tr>
<tr>
<td>Television</td>
<td>SPA</td>
<td>210 3.19</td>
<td>90 3.10</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PUM</td>
<td>208 3.75</td>
<td>90 3.45</td>
<td>4.4</td>
</tr>
<tr>
<td>Computer</td>
<td>SPA</td>
<td>60 3.22</td>
<td>240 3.15</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PUM</td>
<td>60 3.90</td>
<td>238 3.59</td>
<td>3.9</td>
</tr>
<tr>
<td>Internet</td>
<td>SPA</td>
<td>33 3.52</td>
<td>267 3.12</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PUM</td>
<td>33 3.93</td>
<td>267 3.62</td>
<td>3.1</td>
</tr>
<tr>
<td>Piped water</td>
<td>SPA</td>
<td>150 3.11</td>
<td>150 3.21</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PUM</td>
<td>148 3.74</td>
<td>150 3.58</td>
<td>2.6</td>
</tr>
<tr>
<td>Calculator</td>
<td>SPA</td>
<td>99 3.34</td>
<td>211 3.09</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PUM</td>
<td>89 3.66</td>
<td>209 3.65</td>
<td>-</td>
</tr>
<tr>
<td>Mathematics Textbook</td>
<td>SPA</td>
<td>225 3.18</td>
<td>75 3.11</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PUM</td>
<td>224 3.67</td>
<td>74 3.61</td>
<td>-</td>
</tr>
<tr>
<td>Reading Textbook</td>
<td>SPA</td>
<td>224 3.18</td>
<td>76 3.12</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PUM</td>
<td>223 3.67</td>
<td>75 3.63</td>
<td>-</td>
</tr>
</tbody>
</table>
As calculators are not formalized in education in Mozambique, it is possible that some children have not yet appreciated their power for mathematics learning, although they have them and use them under their own initiative. Textbooks are granted by the government to all primary school children, so to have them or not, does not indicate the level of socioeconomic status of the child. About 38% (115) of the children reported to have a cell phone; however, possession of a cell phone did not improve PUM. As most items of the survey form asked about things that exist in the child’s home, it is possible that some children reported having a cell phone that belongs to their family members, even when it is not necessarily used by the child. Another possible explanation is that the children do not associate cell phones with mathematics. The lack of association between mathematics and technology was also noted among parents during interviews. Most parents interviewed believed mathematics is not important for understanding about computers.

**Conclusions and recommendations**

This study was aimed at determining whether there were gender differences on SPA and PUM scores among grade 7 students; comparing parents’ perceptions about their children’s achievement with the children’s self-evaluations; identifying models made up of parental background variables and cultural factors that best predict children’s SPA and PUM scores; and identifying economic resources that have a statistically significant association with students’ SPA and PUM. The major findings of the study were:

1. No gender differences on students’ PUM were noted. Gender differences on SPA were noted only in regard to moral and civic education and benefited girls.
2. Both the girls and the boys revealed their lowest SPA on mathematics and their best on physical education.
3. The students believed mathematics was more useful for them than parents believed it was for their children.
4. Age of child, geo-location, number of siblings, and parent education were the best predictors of students’ PUM but not SPA.
5. Having electricity, TV, computer, internet, and piped water at home were all positively associated with PUM but not SPA.
6. Calculators, cell phones, mathematics and reading textbooks were not statistically significantly related to either SPA or PUM.

It is possible that as mathematics may not be identified with many professions available to the people of Mozambique, and many parents may themselves have had negative experiences in mathematics education, they viewed mathematics as less useful for their children than their children did. The curriculum, expository teaching methods, assessments, and the association
of mathematics with clever people, while physical education is an outdoor activity that engages all pupils, are some of the factors that may have contributed to pupils’ differential self-perceived achievement levels in these subject areas. According to prevalent socio-cultural norms in Mozambican society, girls tend to be more obedient than boys. This might explain why the participating girls had higher perceived achievement levels than boys in moral and civic education. Calculators are valued instruments towards mathematics learning in primary schools in many countries around the world in the 21st century, but in Mozambique this is not the case to date. Thus, non-formal use of these devices to foster mathematics learning outside the classroom may explain why possession of a personal calculator was not related to either SPA or PUM scores.

As indicated earlier, empirical studies aimed at understanding the reasons for children’s poor achievement in mathematics in primary schools in Mozambique are rare. Thus, this study examined the impact of parents, cultural factors, and ownership of selected economic resources on grade 7 students’ beliefs and attitudes towards mathematics learning as a way to contribute to understandings of education in Mozambique. SPA and PUM are desirable objectives of mathematics education in most curricula (Aiken, 1974; Mullis et al., 2008; Reyes, 1984), influence students’ decisions to pursue mathematics courses and related fields (Simpkins et al., 2006), and influence performance (Grootenboer & Hemmings, 2007). Based on the findings from this study, intervention programs aimed at boosting students’ SPA and PUM are recommended. As mathematics does not stand out as being associated with many professions, schools need to develop activities in which they demonstrate the role of mathematics in daily life and in professions to children and their parents. As Wiest and Johnson (2005) recommended, schools should, for example, invite guest speakers to school to explain to children and parents how cell phones and computers work, and which kinds of mathematics and science are involved. As children like cell phones, video games, computers, and calculators, using these devices as learning materials, have the potential to increase students’ understanding of the role of mathematics and their motivation to learn the subject. As parents influence their children’s achievement related behaviours as role models and as expectancy and value socializers (Eccles, 2005; Eccles et al., 1983), schools should assist parents in developing more positive views about mathematics, and about mathematics learning for their children.

In conclusion, although the results from this study were limited in terms of the sample, they suggest the key roles that parental education, geo-location, siblings, age, and possession of selected economic resources (electricity, TV, computer, internet, piped water, and school uniform) may play on students’ PUM in primary schools in Mozambique. Since there are challenges and difficulties in improving the level of socioeconomic status of all families in the short term, it is suggested that appropriate intervention programs that involve parents should be designed and implemented with a view to enhancing primary school children’s perceived usefulness of mathematics. When involving parents, such activities are likely to improve children’s PUM.

References


Relevance and school mathematics

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Abstract
The theme of SAARSMTE 2013 conference is Making Mathematics Science and Technology Socially and Culturally Relevant in Africa. This paper will focus on mathematics and relevance in schools. I will start by discussing briefly the importance of paying attention to cultural relevance and social relevance. Then I will focus on students’ interest as one of the aspects of relevance. I will present findings of a small survey conducted in Malawi which was adapted from a very large cross country project. I argue that relevance for students includes their interests, and therefore should be considered. Interest yields motivation and meaningful learning which mathematics teaching aims for. I conclude by raising more questions than answers for implications to curriculum development, teacher knowledge and teacher education.

Introduction
The need for relevance in education is reflected in many countries’ national documents. For example, Malawi has the following in its Education Sector Implementation Plan 2009-2013 “Malawi will make its main strategic priority the improvement of quality, equity, relevance, access and efficiency in basic education” (Government of Malawi, 2009; page 20). However, these documents do not clearly describe what they mean by relevance, or how this relevance can be achieved.

According to Greer and Skovsmose (2012), socially relevant mathematics education can be described as that which connects with the present and future lives of students as well as the issues that are of importance to them and their communities, and in the interest of humankind in general. While culturally relevant education is one “that empowers students intellectually, socially, emotionally and politically by using cultural referents to impart knowledge, skills and attitudes” (Ladson-Billings, 1994:17-18). Thus both social and cultural relevance are about connecting with students' lives and acknowledging their cultures, and embedding these into curriculum and teaching.

In this paper I look at relevance in terms of what students would find interesting to learn as content and contexts in mathematics. I argue that what is of interest to students is relevant to them and also motivating, therefore, important to mathematics education.

Why pay attention to social and cultural relevance?
Learners are part of some culture and some social context, and these social and cultural contexts form part of who they are and how they view the world. Education needs to pay attention to these aspects of learners’ lives because one of the goals of education is to develop appropriate socio-cultural skills in learners as well as to develop learners’ appreciation of their culture and respect of other people’s cultures (Malawi of Education, 2011). In mathematics teaching specifically it is important to consider social and cultural relevance for the following reasons, which are not exhaustive.
Application of mathematics to learners’ contexts
Learners can apply mathematics to their contexts if made relevant. For example, Gibbs (1992) reports of a *Health into Mathematics* project that paid attention to health issues of a schools community. For instance, they taught ratio using the context of salt and sugar solution which is given to diarrhoea patients. Diarrhoea was common in this community and children learnt how to make the solution in mathematics class while at the same time learning the concepts of ratio. Such examples of application of mathematics to learners’ contexts motivate learners as they see the use of mathematics in their everyday lives. See Gibbs and Mutunga (1991) for more examples of such activities.

Learners to see mathematics around them
Mathematics is all around us and sometimes in places where learners least expect, for example in mat weaving (Cherinda, 2012), basket weaving and in many cultural handmade decorations (Gerdes, 1998). Relating mathematics to such artifacts in communities gives learners the opportunity to see and appreciate the mathematics around them (Gerdes, 1998; Cherinda, 2012).

Learners learn of issues that affect them
There are many issues that affect learners’ communities especially in rural areas. For example in Malawi many rural areas are affected by environmental degradation, health problems especially HIV and AIDS, and nutrition problems. Using the mathematics classrooms to relate to these issues helps learners understand the issues and how to alleviate or reduce of them. This way, mathematics classroom is not viewed as isolated from their environment but one that relates to them and therefore of interest. Blum (2012) and Niss, Blum, and Galbraith (2007) call this teaching of extra-mathematics. It is important to note that this extra-mathematics is planned and goes beyond using issues as context for mathematical problems. Once the mathematics is taught, the issue is discussed with the aim of teaching some lessons about the issue.

Teaching social responsibility
Relating to learners social and cultural issues creates an opportunity for learners to become socially responsible citizens. Onwu and Kyle (2011) argue that in this millennium we cannot continue teaching science the way it was taught more than fifty years ago when many of the environmental issues we face today were not a problem. They argue for socially responsive science education, and the same can be argued for mathematics education.

Education of future experts
Social relevance also means educating experts for the future - those that will take the field forward. These are teachers and researchers in mathematics, science, engineering, and other related disciplines. A good example of an African mathematician that uses mathematics to assist Africa is Professor Edward Lungu of University of Botswana. He has received international recognition and was awarded the 2011 International Congress on Industrial and Applied Mathematics (ICIAM) Su–Buchin Prize for developing mathematical models of problems related to his country and Africa. He was also recognised for his contribution to developing teaching and research of applied mathematics in Southern Africa. Professor Lungu’s mathematical modelling were in (i) hydrology (Botswana relies on storing rainfall), (ii) ecology (livestock and wildlife are vital to Botswana’s economy) and (iii) epidemiology (to understand progression of HIV and AIDS in people and how to help them) (ICIAM, 2012; International Mathematical Union, 2009).
By researching and developing mathematical models in these three areas, Prof Lungu is considered one of the few that has responded to the needs of his country and southern Africa. According to ICIAM “he has simply done everything that one person could do: organized, encouraged, supervised, and led by his personal example in teaching and research” (ICIAM, 2012). We need more of such experts for the future; experts that combine their expertise with social responsibility (Greer and Skovsmose, 2012).

Who decides on relevance?
Issues of relevance are often decided by a number of groups of people including policy makers, curriculum developers, textbook writers, and class teachers. Policy makers are often guided by the issues affecting the nation at the time. For example, in Malawi, policies are guided by the Malawi Growth and Development Strategies (MGDS), MGDS (2006-2011) and now MGDS II (2011–2016) (Malawi Government, 2012). Curriculum developers interpret the policies and develop the curriculum as they see ‘relevant’ to the nation’s needs. Textbook writers interpret the curriculum into a possible form of teaching. Finally teachers interpret both the curriculum and the textbooks into lessons. The teacher seems to be the one with the most influence on what ‘relevance’ she or he can bring to the mathematics lesson.

All the groups of people from the policy makers to the teachers can consult the community and other stakeholders in their quest for relevance. Therefore, in theory, all adults can have a say in what is relevant in schools. The group that seems to be missing in giving their views of relevance is the students. In particular, what is missing is what the students would prefer to learn or find interesting as contexts in school mathematics (Julie and Holtman, 2008). It could be argued that students would not know what is good for them, however, interest has been shown to be a very important aspect that motivates learners (Julie 2012). I argue that we can indeed decide for students but we also need to consider their interests; otherwise our efforts might be fruitless if learners are not motivated to learn.

Students’ interests as an aspect of relevance
What students find interesting is relevant to them, and what is interesting to students is also motivating to them and therefore relevant to teaching and learning. Researchers that have studied students’ interests in mathematics and mathematics contexts include: Kaiser-Messmer (1993), Julie and Mbekwa (2005), Julie (2007), Julie and Holtman (2008), Ndemo and Mtetwa (2010), Kacerja, Julie and Hadjerrouit (2010), Kacerja (2011), Holtman, Julie, Mbekwa, Mtetwa and Ngcobo (2011), and Julie (2012). I will discuss some of these briefly below:

Kaiser-Messmer (1993), in her study that investigated differences between male and female students in school mathematics in Germany, found that in lower secondary school there were larger differences in preferences than in upper secondary. In lower secondary male students had strong preference for sport, technology, economy, and physics, and in upper secondary the strong preferences were society and technology. While females in lower secondary preferred ecology, sport, biology/medicine and everyday life and in upper secondary social topics, ecology and everyday life. In more advanced courses the differences were smaller where both males and females had strong preferences for technology, while biology and medicine was mostly preferred by females than males.

Julie and Holtman (2008) report on a multi country project called Relevance of School Mathematics Education (ROSME) which involved Norway, South Africa, South Korea, Swaziland, Uganda and Zimbabwe. One of the main findings of this project was that
technology, and in particular modern technology is of great interest to students in all the countries. They observed differences in some preferences by student from highly developed countries and those from developing countries, which seemed to be related to the level of development of their countries. For example, ‘mathematics relevant to professionals such as engineer, lawyers and accountants’ was rated among the top five by South Africa, Swaziland, Uganda and Zimbabwe and rated low by Norway and South Korea, while the reverse was true for ‘mathematics of the lottery and gambling’. Some more details about ROSME and findings will be discussed later in the paper when comparisons with Malawi findings are made.

Ndemo and Mtetwa (2010) analysed Zimbabwe ROSME data for gender differences and found that boys showed higher preferences than girls for science and technology related contexts while girls showed higher preferences than boys for care-giving related contexts such as “mathematics to prescribe the amount of medicine a sick person must take”. The students that formed the sample for this study were drawn from rural environments, where often girls are exposed to care-giving situations more than boys. The findings seem to support the earlier findings by Kaiser-Messmer (1993).

Kacerja (2011) explored reasons for students’ interests and preferences in Albania schools. This study was a follow up of Kacerja, Julie and Hadjerrouit (2010) where students’ interests and preferences were determined. The study offered lessons that were deliberately designed for specific contexts and later interviewed a sample of students about the contexts they preferred and the reasons. One of the findings was that students’ preferences were influenced by the mathematics topic and its level of difficulty. Kacerja (2011) cautions that preferences by students should therefore be considered with care.

Julie (2012) in a follow up project, ROSME II, investigated stability of students' interest by administering a revised questionnaire to same level of students four years later. An interesting finding was that students’ interests remained fairly stable across the two cohorts. Besides the specific lessons that we can learn from each of these studies, we also learn that it is possible to explore and determine what students’ interests are and this knowledge can inform development of curriculum and curriculum materials.

Malawi study
The study was adapted from ROSME project (Julie and Holtman, 2008). A sample of 346 secondary school students in Malawi were asked to answer the question “what kind of mathematics would you like to learn?” by indicating their level of interest on a four point scale adapted from Julie and Holtman (2008). For each of the 27 items, students were asked to circle one of the four options: 1 (not at all interested), 2 (a bit interested), 3 (quite interested) and 4 (very interested). A copy of the questionnaire can be found in the appendices.

Twenty five of the items were adapted from ROSME project while two were constructed from the current issues in Malawi; one from issue of population (Mathematics of studying population growth and the impact on communities) and the other from issue of climate change and environment (Mathematics involved in studying issues of climate change and the environment). The 25 items from ROSME were selected from the top 10 most preferred and bottom 10 least preferred, and others that were considered ‘relevant’ for Malawi. Seven of the items were modified to suit Malawi context. Below are three example of items that were modified; the first column is the original ROSME item while the second is the modified
Malawi version. The third column gives the reason for modifying. A similar table containing all the seven modified items is given in the appendix.

Table 1: Examples of modified items

<table>
<thead>
<tr>
<th>Original version</th>
<th>Modified version for Malawi</th>
<th>Reason for modifying</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics linked to decorations such as the house decorations made by Ndebele women</td>
<td>Mathematics linked to weaving baskets and mats such as mikeka</td>
<td>Common Ethnomathematics is in weaving not decorations</td>
</tr>
<tr>
<td>Mathematics involved for deciding the number of cattle, sheep or reindeer to graze in a field of a certain size</td>
<td>Mathematics involved for deciding the number of cattle, goats or sheep to graze in a field of a certain size</td>
<td>Reindeer is not a familiar animal, while goats are very common livestock</td>
</tr>
<tr>
<td>How mathematics can be used in sport competitions like ski jumping, gymnastics, swimming, athletics and soccer</td>
<td>How mathematics can be used in sport competitions like football, netball and athletics</td>
<td>Football, netball and athletics are very common and familiar to Malawi students. Ski jumping and gymnastics are not familiar at all.</td>
</tr>
</tbody>
</table>

The Malawi sample of students was taken from four secondary schools in Zomba. All students were in the final term of Form 3, which means that by that time they had about 3 years of secondary school mathematics. Of the 346 students, there were 144 females and 202 males. Their ages ranged from 14-21, with most being 15-17 years old. The students were mostly from rural and some from semi-urban communities. This sample was typical of Malawi secondary student population. I administered the questionnaire to all students in their classrooms, and I explained the questionnaire and the purpose before they responded.

The 27 items were ordered randomly on the questionnaire; the items were listed in Excel and assigned random numbers, then listed in order of magnitude of the random numbers. Analysis used SPSS and Excel to get frequencies in (a) descending order of very interested, (b) descending order of sum of quite and very interested, (c) ascending order of not at all interests, (d) ascending order of not and a bit interested. Note that (b) and (d) were not identical because of some omissions by students in their responses. The four orders were used to classify into three; top 9, bottom 9, and middle 9. The same analysis was done for males and females as separate sub groups to check differences in ratings between the genders.

Theoretical orientation
The theoretical underpinning of the study is drawn from Interest and Motivation theory (Kunter, Baumert and Koller, 2007) that the level of interest in a subject is associated with learning behaviours in the subject, in this case mathematics. Therefore, it is essential to acknowledge that students have interests and preferences in the mathematics and mathematics contexts they learn in schools and these interests can inform mathematics education.

Results and Discussion
Table 2 below shows the overall students’ rating from ‘of most interest’ to ‘of least interest’.
Table 2: Top 9 rating by Malawi students (in descending order from most preferred)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mathematics that will help me to do mathematics at universities or other colleges</td>
</tr>
<tr>
<td>2</td>
<td>Mathematics that is relevant to professionals such as engineers, lawyers and accountants</td>
</tr>
<tr>
<td>3</td>
<td>Mathematics to prescribe the amount of medicine a sick person must take</td>
</tr>
<tr>
<td>4</td>
<td>Mathematics involved in working out financial plans for profit-making</td>
</tr>
<tr>
<td>5</td>
<td>Mathematics involved in making computer games, cell phone games and TV games</td>
</tr>
<tr>
<td>6</td>
<td>Mathematics involved in secret codes such as pin numbers used for withdrawing money from an ATM</td>
</tr>
<tr>
<td>7</td>
<td>Mathematics of studying population growth and the impact on communities</td>
</tr>
<tr>
<td>8</td>
<td>Mathematics involved in sending of messages by SMS, cell phones and e-mails</td>
</tr>
<tr>
<td>9</td>
<td>Mathematics to assist in the determination of the level of development regarding employment, education and poverty of my community</td>
</tr>
</tbody>
</table>

The top 9 preferences can be categorized as further education (1), high level professionals (2), health (3), business or entrepreneurial activity (4), modern technology (5, 6 and 8), and community (7 and 9). Interesting to note is the fact that the highest two preferences and also the fourth are the ones that seem to offer future prospects of a better life. Modern technology attracted a lot of interest, similar to findings of previous studies. The issue of population and impact on communities which was constructed from current issues in Malawi was rated highly, and it is intriguing to note that learners seem to be interested in issues that affect them and their community. This is supported by their interest in ‘level of development, education and poverty of my community’, although not so high in the rating.

Table 3: Bottom 9 rating by Malawi students (in ascending order from least preferred)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>Mathematics linked to weaving baskets and mats e.g. mikeka</td>
</tr>
<tr>
<td>26</td>
<td>Mathematics linked to clothes and shoes</td>
</tr>
<tr>
<td>25</td>
<td>Mathematics involved in assigning people to tasks when a set of different tasks must be completed</td>
</tr>
<tr>
<td>24</td>
<td>Mathematics of a lottery and gambling</td>
</tr>
<tr>
<td>23</td>
<td>Mathematics to determine the number of fish in a lake, river or dam</td>
</tr>
<tr>
<td>22</td>
<td>Mathematics involved in designing delivery routes of goods such as delivering Coca-Cola from the factory to the shops</td>
</tr>
<tr>
<td>21</td>
<td>Mathematics about renewable energy sources such as wind and solar power</td>
</tr>
<tr>
<td>20</td>
<td>How mathematics can be used in sport competitions like football, netball and athletics</td>
</tr>
<tr>
<td>19</td>
<td>Mathematics involved for deciding the number of cattle, goats or sheep to graze in a field of a certain size</td>
</tr>
</tbody>
</table>
Classifying these least preferred items gives a variety of categories; ethnomathematics, fashion, productively, societal behaviour, environmental issues, transportation, energy, sports and agriculture; in the order from least preferred. On one hand, I find it surprising that they would rate ethno-mathematics as the least interesting of all, and also environment, energy and agriculture among the least 9, because one would expect these to be part of their everyday lives and of interest to them. On the other hand, when I consider that the most preferred were things that offer future prospects, I note that 'weaving', 'grazing' and 'fishing' are some of the jobs that, in Malawi, are not related to education because they are done by many who have no education at all or dropped out of school.

Table 4: Middle 9 rating by Malawi students (in descending order)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Mathematics used in making aeroplanes and rockets</td>
</tr>
<tr>
<td>11</td>
<td>Mathematics used to calculate the taxes people and companies must pay to the government</td>
</tr>
<tr>
<td>12</td>
<td>Mathematics needed to work out the amount of fertilizer needed to grow a certain crop</td>
</tr>
<tr>
<td>13</td>
<td>Mathematics involved in studying issues of climate change and the environment</td>
</tr>
<tr>
<td>14</td>
<td>Mathematics involved in determining the state of health of a person</td>
</tr>
<tr>
<td>15</td>
<td>Mathematics involved in working out the best arrangement for planting seeds</td>
</tr>
<tr>
<td>16</td>
<td>Mathematics involved in working out the best arrangement for planting seeds</td>
</tr>
<tr>
<td>17</td>
<td>The personal life stories of famous mathematicians</td>
</tr>
<tr>
<td>18</td>
<td>Mathematics about the age of the universe</td>
</tr>
</tbody>
</table>

The middle 9 can be classified into the categories of technology, finance, agriculture, environment, health, history and universe. Interesting to note is that the technology was 10th thus nearest the top 9. We also note that it was simply technology and not necessarily modern technology, as those in top 9. A summary of the categories are listed in table 5.

Table 5: Summary of categories

<table>
<thead>
<tr>
<th>Rank</th>
<th>Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top 9</td>
<td>Modern Technology, Further studies, High level professional, Health, Entrepreneurial activity, Community, Population,</td>
</tr>
</tbody>
</table>

Comparison between genders

Below is a bar graph that shows distribution of age across gender. In general we note that girls were on average younger than boys. We also note that there were many more boys than girls; 202 versus 144, as was indicated earlier.
When I compared the ratings for girls and for boys I found that the two were similar. It was interesting to note that modern technology was of great interest to both. What was intriguing was that the top 9 items remained the same for both with a slight difference in the order. Girls rated the item on population and community higher than the item on profit making, while boys rated the profit making item higher than the health item. Looking at the rest of the ranking, again there were similar but with slight differences in ordering. One of the noticeable things was that girls rated all the health issues higher than boys did, while boys rated ‘age of the universe’ and ‘renewable energy sources’ higher than girls. This is similar to the findings of Ndemo and Mtetwa (2010) where girls showed higher preferences to caregiving situations than boys. The finding that both boys and girls showed high interest in modern technology seem to be a little in contrast to the finding by Keisser (2008) where she found boys preferring technology while girls preferred health and society issues more. However, in advance mathematic classes, she did find that both boys and girls preferred technology. These findings seem to support that finding, even though these were not advance mathematics classes. The findings also support that girls seem to prefer health issues more than boys.

Comparison with ROSME
Items that students were most interested in
Six of the top 9 for Malawi (2, 3, 4, 5, 6, and 8) were among the top 10 for ROSME project but in different order. These were: Mathematics that is relevant to professionals such as engineers; lawyers and accountants; Mathematics to prescribe the amount of medicine a sick person must take; Mathematics involved in working out financial plans for profit-making; Mathematics involved in making computer games, cell phone games and TV games; Mathematics involved in secret codes such as pin numbers used for withdrawing money from an ATM; and Mathematics involved in sending of messages by SMS, cell phones and e-mails.

The top most for Malawi (Mathematics that will help me to do mathematics at universities or other colleges) did not feature among the top for ROSME, while the top most for ROSME, which was about “secret codes such as pin numbers used for withdrawing money from an ATM”, was rated 6th for Malawi. Both groups were interested in modern technology which appears to inform us that students in general, regardless of contexts, are curious about modern
technology and would be motivated by modern technology mathematics and mathematics contexts.

**Items that students were least interested in**

Seven of the bottom 9 for Malawi (27, 26, 25, 24, 23, 22 and 19) were also among the bottom 10 for ROSME project. These were; Mathematics linked to weaving baskets and mats; Mathematics linked to clothes and shoes; Mathematics involved in assigning people to tasks when a set of different tasks must be completed; Mathematics of a lottery and gambling; Mathematics to determine the number of fish in a lake, river or dam; Mathematics involved in designing delivery routes of goods; and Mathematics involved for deciding the number of cattle, goats or sheep to graze in a field of a certain size.

The item of least interest for ROSME was about “best arrangements for planting seeds” which was rated relatively higher for Malawi. This seems to reflect the importance of Agriculture for Malawi; many household depend on agriculture for livelihood. In contrast, the item about “mathematics used in sport competitions” was rated very low for Malawi while it was rated very highly for ROSME. This also seems to reflect the Malawi context where sport is generally considered as a recreation and not a profession.

Both groups were not at all interested in Ethno-mathematics. The item was rated last for Malawi and last but one for ROSME. This is an important finding which needs to be explored further because Ethno-mathematics is one of the ways of linking mathematics to culture, and it is often assumed that students would be interested in these.

**Discussion of findings**

Findings of the study support findings from previous studies that students have interests and preferences of the mathematics and mathematics contexts they would like to learn, and these can be determined. Mathematics that offer future prospects; further education, high level professions, and profitable business; were highly preferred by Malawi students. On one hand this seems to reveal the socio economic status of the students and their desire for better livelihoods. On the other hand it might be revealing the way mathematics is taught in Malawi schools - as something that is useful for future prospects only. The students indicated more interest in modern technology than issues of agriculture and the environment. This is intriguing because one might expect that they would be more interested in issues that relate closely to their livelihoods than what could be considered luxury in some communities. One possible explanation for this is that students are curious about how modern technology works. This curiosity yields motivation which mathematics educators can exploit. Another explanation is that the issues of agriculture and environment are often associated with low income, and therefore not what students aspire for. For example the items on 'grazing land' and on 'number of fish' were rated very low probably because both fishing and grazing livestock are jobs that are associated with school dropouts or people that have never attended school.

These findings are important because as others (e.g. Julie (2012)) have argued, knowledge of students’ interests could inform curriculum developers and guide them to add new mathematics topics to the curriculum. According to the top 9 most preferred by Malawi students, the mathematics that would cover these would include abstract algebra, coding theory, cryptography, financial mathematics, game theory, differential equations, logic, probability, queuing theory, statistics, and trigonometry. Apart from coding theory, cryptography, differential equations, and queuing theory, aspects of the others are already present in the Malawi curriculum. The essential part is for us to present these to students in a
way that interests them. Mathematics involved in modern technology, which students have shown great interest in, include coding theory, cryptography and queuing theory. Elementary aspects of these could be introduced to secondary mathematics.

Knowledge of students’ interests could also inform textbook writers and authors of other curriculum materials to include as contexts. Julie (2012) has shown that learners’ interests are quite stable, therefore the inclusion of new mathematics topics in curriculum and new contexts in curriculum materials seems reasonable. However, having new topics in curriculum does not guarantee sustained students interests. What would be crucial is how we teach the topics.

**Implications of findings**

**Implications for Curriculum Development**

Inclusion of new topics and contexts that address students’ interests is a major implication for development of curriculum and curricula materials. There are further implications of this, such as: how do we address differences in interests between communities and cultures?; What would be the time frame of addressing students’ interests?; and many more. These implications need to be carefully considered before any drastic steps are taken.

**Implications for Teacher Knowledge**

It is well known that there are many forms of teacher knowledge including Pedagogical Content Knowledge (PCK) (Shulman, 1986). PCK includes knowledge of content and knowledge of students. The findings suggest that knowledge of students should go beyond students’ strategies, errors and misconceptions. It should also include the students' interests in mathematical content and contexts. Similarly, content knowledge should also include students’ interest.

It is also known that teachers engage in mathematical problem solving as they prepare lessons and as they teach mathematics (Ball, Bass and Hill, 2004; Adler, 2005; Kazima and Adler, 2006). Considering students' interests in teaching mathematics make further mathematical problem solving demands on the teacher. These demands include; offering different representations for mathematical content, such as story representations and word problems of the contexts students are interested in; and restructuring of tasks such as modifying contexts to suit students’ interests.

**Implications for Teacher Education**

Teacher education is a huge task and cannot offer all the knowledge and skills that teachers require for effective teaching of mathematics. However, teacher education should, among other things, attempt to prepare teachers such that: (i) they are aware of the many different forms of knowledge that they need for teaching and why; (ii) they can acquire the additional knowledge in practice; (iii) they can adapt to different contexts and situations; and (iv) they can reflect and learn from their own practice and from research.

There are further implications which should be considered including the following: (i) what can be included in teacher education courses? (ii) what can be learnt in practice? and (iii) how do we know the difference?

**Conclusion**

In conclusion, I would like to stress that it could be argued that students would not know what is good for them, and therefore we should decide for them. I agree that curriculum and
teaching cannot be driven by students’ interests alone, and we can indeed on the large part
decide for students. However, interest has been shown to be a very important aspect that
motivates learners and therefore we also need to consider these interests so that the students
are motivated to learn mathematics.
While many policy makers, curriculum developers, textbook writers and other groups of
people can make decisions about the mathematics and the mathematics contexts that students
can use to learn mathematics, teachers are the implementers. Thus teachers make the final
call on how to teach and what contexts to use. Therefore, in my view, the most important is
teacher knowledge. With the appropriate knowledge, teachers can make a large difference.
The crucial question is: where and how can teachers acquire this knowledge?

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Government
Government
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### Appendix A: Table showing items that were modified & reasons

<table>
<thead>
<tr>
<th>Original version</th>
<th>Malawian version</th>
<th>Reason for modifying</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics linked to decorations such as the house decorations made by Ndebele women</td>
<td>Mathematics linked to weaving baskets &amp; mats such as <em>mikeka</em></td>
<td>Common ethomathematics is in weaving not decorations</td>
</tr>
<tr>
<td>Mathematics involved for deciding the number of cattle, sheep or reindeer to graze in a field of a certain size</td>
<td>Mathematics involved for deciding the number of cattle, goats or sheep to graze in a field of a certain size</td>
<td>Reindeer is not a familiar animal, while goats are very common livestock</td>
</tr>
<tr>
<td>Mathematics involved in designing delivery routes of goods such as delivering bread from a bakery to the shops</td>
<td>Mathematics involved in designing delivery routes of goods such as delivering Coca-Cola from the factory to the shops</td>
<td>Most common delivery truck is Coca-Cola</td>
</tr>
<tr>
<td>How mathematics can be used in sport competitions like ski jumping, gymnastics, swimming, athletics &amp; soccer</td>
<td>How mathematics can be used in sport competitions like football, netball &amp; athletics</td>
<td>Football, netball &amp; athletics are very common &amp; familiar to Malawi students. Ski jumping &amp; gymnastics are not familiar at all.</td>
</tr>
<tr>
<td>Mathematics to determine the number of fish in a lake, river or a certain section of the sea</td>
<td>Mathematics to determine the number of fish in a lake, river or dam</td>
<td>There is no sea around Malawi so a dam, which is common, is more familiar</td>
</tr>
<tr>
<td>Mathematics involved in making computer games, such as play stations &amp; TV games</td>
<td>Mathematics involved in making computer games, cell phone games &amp; TV games</td>
<td>Play stations are not familiar, while cell phones are common &amp; many have games</td>
</tr>
<tr>
<td>Mathematics that will help me to do mathematics at universities or technikons</td>
<td>Mathematics that will help me to do mathematics at universities or other colleges</td>
<td>Malawi has no technikons but has a number of colleges apart from Universities.</td>
</tr>
</tbody>
</table>
Appendix B: Questionnaire for students

RELEVANCE OF SCHOOL MATHEMATICS: STUDENTS’ QUESTIONNAIRE

I am: female/male _________ I am _______ years old I am in Form __________

What would you like to learn about in mathematics? Some possible things are in the list below. Beside each item in the list, circle only one of the numbers in the boxes to say how much you are interested. Please respond to all the items.
1 = Not at all interested
2 = A bit interested
3 = Quite interested
4 = Very interested

There are no correct answers: we want you to tell us what you like.

<table>
<thead>
<tr>
<th>Things I’d like to learn about in Mathematics</th>
<th>Not at all interested</th>
<th>A bit interested</th>
<th>Quite interested</th>
<th>Very interested</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mathematics involved in making computer games, cell phone games &amp; TV games</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2 Mathematics linked to weaving baskets &amp; mats such as mikeka</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3 Mathematics involved in sending of messages by SMS, cellphones &amp; e-mails</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4 Mathematics involved in determining the state of health of a person</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5 Mathematics of a lottery &amp; gambling</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6 Mathematics used to calculate the taxes people &amp; companies must pay to the government</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>7 Mathematics to prescribe the amount of medicine a sick person must take</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>8 Mathematics involved in designing delivery routes of goods such as delivering Coca-Cola from the factory to the shops</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>9 Mathematics involved in assigning people to tasks when a set of different tasks must be completed</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>10 Mathematics involved in studying issues of climate change &amp; the environment</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>11 How mathematics can be used in sport competitions like football,</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>netball &amp; athletics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>-------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Mathematics that is relevant to professionals such as engineers, lawyers &amp; accountants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Mathematics of studying population growth &amp; the impact on communities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Mathematics to determine the number of fish in a lake, river or dam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Mathematics involved for deciding the number of cattle, goats or sheep to graze in a field of a certain size</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Mathematics used in making airplanes &amp; rockets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Mathematics needed to work out the amount of fertilizer needed to grow a certain crop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Mathematics involved in secret codes such as pin numbers used for withdrawing money from an ATM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Mathematics that will help me to do mathematics at universities or other colleges</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Mathematics about renewable energy sources such as wind &amp; solar power</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>The personal life stories of famous mathematicians</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Mathematics about the age of the universe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Mathematics involved in working out financial plans for profit-making</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Mathematics involved in working out the best arrangement for planting seeds</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Mathematics used to predict the growth &amp; decline of epidemics such as AIDS, TB &amp; Cholera</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Mathematics linked to clothes &amp; shoes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Mathematics to assist in the determination of the level of development regarding employment, education &amp; poverty of my community</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Designing a PCK framework for the professional development of statistics teachers

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Abstract
High-quality statistics teacher education and development is crucial if educational delivery in South Africa is to be improved. Shulman presents pedagogical content knowledge as a separate and unique domain of knowledge necessary for the teachers of all subjects. Based on the experience as a statistics teachers for many years and on the literature on pedagogical content knowledge for teachers from several researchers based on Shulman this paper proposes the design of a pedagogical content knowledge framework that guides the development of pedagogical content knowledge of secondary school statistics teachers during professional development.

It is against this background that the paper aimed to clarify the design of a pedagogical content knowledge framework using a section of statistics, bivariate data, which guides the development of pedagogical content knowledge of secondary school statistics teachers during professional development. The paper therefore describes and discusses the implications of a pedagogical content knowledge framework for statistics education. Conceptual frameworks, against which the pedagogical content knowledge framework for the development of Grade 11 and 12 statistics teachers were developed, are discussed. The goal of the pedagogical content knowledge framework was based on the need to help teachers during professional development to be competent and confident in teaching Grade 11 and 12 statistical concepts. Furthermore it helped teachers to be reflective of their instructional practice in ways that can improve the teaching of statistics concepts. The reflective accounts shared between the statistics teachers and the researcher enabled the continual improvement of the statistics pedagogical content knowledge framework. The unique characteristic of the framework is that allows the integration of technicalities and complexities of the theory and practice of teaching using pedagogical content knowledge and also gives room for improvement during and after each professional development for both the educators and the teachers. Through the PCK framework developers can be better positioned to plan, implement and access ways to improve teachers understanding of the subject they teach. This paper stimulates national and cross-national dialogue among policy makers and educators regarding programs and curricular to improve preparation and practice in secondary school statistics.

Key words: pedagogical content knowledge, pedagogical content knowledge framework, secondary school statistics, professional development, teacher knowledge

Introduction
This paper was prompted by the inclusion, in 2003,of additional statistics concepts in South Africa’s secondary school mathematics curriculum, marking a significant change in the way the subject would be taught. Indeed, the move has given rise to much discussion on the way statistics is taught in South African secondary schools. The new curriculum was endorsed by the Department of Education (2003, 2004) in a bid to improve the quality of statistics education for South African citizens. The announcement of Curriculum 2005 (C2005) followed this endorsement. C2005 included outcomes-based education (OBE) as a
fundamental building block and represented the start of a whole new era in school education in South Africa. The statistics component of curriculum C2005 (then referred to as data handling) covered aspects in FET (Further Education and Training), Mathematics Grade 10 to 12. In 2007, Compulsory Assessment Standards were included in the C2005 curriculum for Grade 11 and 12 (Department of Education (2007:22). However most teachers have not learnt statistics at school, evident through the poor student performance in this area nationally and internationally, yet, they are being left with the task of teaching it to the learners (ISTEs Winter School Report, 2009. Furthermore the focus of the way statistics must be taught at international level has shifted from a curriculum dominated by memorization of isolated facts and procedures to statistical thinking, a focus that emphasizes conceptual understandings, multiple representations and connections (Craine & Rubenstein 1993:30). Statistical literacy is the ability to understand and critically evaluate statistical results that permeate our daily lives coupled with the ability to appreciate the contributions that statistical thinking can bring to the making of professional and personal decisions, both public and private. Some of the activities in which teachers regularly engage in, such as finding out what students know and choosing and managing representation of mathematical ideas involve mathematical reasoning and thinking (Ball et al 2001:453). These are some of the most important aspects of pedagogical content knowledge and hence give rise to the need to present a framework for the development of such knowledge.

While many professional development programmes have been offered in South Africa, but however inadequacies have certainly been observed in the programmes. According to the Trends in International Mathematics and Science Study (TIMSS) (2003:20) report, South African teachers attend the highest number of professional courses, compared to other countries, offered by the Department of Education, universities and non-governmental organisations yet there is no clear evidence of any positive impact that these courses might have on teachers performance. Current models of professional development fail to accurately address and outline the role of pedagogical content knowledge in the professional development of teachers. In-service education continues to rely on brief summer workshops followed by a small number of brief, school-based observations, demonstrations or discussions (Kesh & Lovitts in Kelly & Lesh 2000:44). Brief summer workshops with no meaningful follow ups from the presenters cannot benefit the teachers adequately. Teacher training programmes offered have no effective supervision and evaluation systems in place as evidenced by general discussions during the Association for Mathematics Education of South Africa (AMESA) conferences. Based on the above discussion, better-focused teacher knowledge (specifically, pedagogical content knowledge) is needed.

Contrary to general opinion, the nature and praxis of teaching make it one of the most difficult professions. Success in teaching depends on factors completely different from those that come into play in other professions. These include factors beyond the teacher’s control such as the willingness of learners to actively cooperate. Adding to the difficulty of the teaching praxis is that, unlike with other professions where clients have the option of “going back to the expert” every time they have a problem, teachers have to first master their disciplines and secondly, provide learners with the capacity to “figure it out for themselves” the next time around, (Labaree,2000). According to Ball (2000), subject matter and pedagogy have been peculiarly and persistently divided in the conceptualisation and curriculum of teacher education and learning to teach. This fragmentation of practice leaves teachers on their own with the challenge of integrating subject matter knowledge and pedagogy in the contexts of their work. Yet, being able to do this is fundamental to engaging in the core tasks
of teaching, and it is critical to being able to teach all students well. This article proposes a pedagogical content knowledge framework which aims to bridge this gap and to prepare teachers who not only know content but can make use of it to help all students learn. This is done through identifying the content knowledge that matters for teaching, understanding how such knowledge needs to be held, and thinking seriously about what it takes to learn to use such knowledge in practice Ball (2000). This study encourages teaching approaches that are complementary to learning principles outlined in pedagogical content knowledge and are clarified in the pedagogical content knowledge framework.

This paper clarifies the design of a pedagogical content knowledge framework that guides the development of the pedagogical content knowledge of secondary school statistics teachers during professional development. The framework, using bivariate data, is designed and broadly described, and its potential for use in professional development is discussed. The paper further describes and discusses the implications of a pedagogical content knowledge framework for statistics education. Conceptual frameworks, against which the pedagogical content knowledge framework for the development of Grade 11 and 12 statistics teachers was developed, are discussed. The goal for the design of the pedagogical content knowledge framework was based on the need to guide teachers undergoing professional development towards being competent and confident in teaching Grade 11 and 12 statistical concepts. Furthermore it helped teachers to be reflective of their instructional practice in ways that can improve the teaching of statistics concepts. The reflective accounts shared between the statistics teachers and the researcher during the development of pedagogical content knowledge enabled the continual improvement of the statistics pedagogical content knowledge framework. The unique characteristic of the framework is that it allows the integration of technicalities and complexities inherent in the theory and practice of teaching using pedagogical content knowledge, and it also leaves room for improvement during and after each professional development session for both educators and teachers.

**Pedagogical content knowledge**

There is widespread agreement that effective teachers have unique knowledge of students' mathematical ideas and thinking (Hill, Ball, & Schilling : 2008). However, few scholars have focused on conceptualizing this domain. Pedagogical content knowledge is Shulman’s answer to the old question: “Which is more important in a teacher, knowledge of the subject matter or general ability to teach?” Since the 1980s the analytic distinction between teachers’ subject matter knowledge and teachers knowledge of pedagogy has begun to fade in large part, due to Shulman’s (1986, 1987) work. Shulman pointed out that the best teacher has something that is neither of these but instead has knowledge of how to teach specific parts of the subject matter. Shulman (1986) developed a new framework for teacher education by introducing the concept of pedagogical content knowledge which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching. Rather than viewing teacher education from the perspective of content or pedagogy, Shulman (1986) believed that teacher education programs should combine these two knowledge bases to pedagogical content knowledge to more effectively prepare teachers.

In the years following Shulman (1986)’s seminal address on the introduction of the notion of pedagogical content knowledge, most scholars and policy makers have assumed that such knowledge not only exists but also contribute to effective teaching and learning (Rowan, Schilling, Ball & Miller 2001:2). Pedagogical content knowledge (PCK) includes the most useful forms of representation of topics, the most powerful analogies, illustrations,
examples, explanations, and demonstrations - in a word, the ways of representing and formulating the subject that make it comprehensible to others Shulman(1987: 9).

Also encapsulated in the idea of PCK is the notion that successful teachers have a special knowledge about learners which informs their teaching of particular content. Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult for others and acknowledges the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons Shulman(1987: 9).

The ideas of PCK espoused by Shulman (1986) have been the cornerstone of the development of pedagogical content knowledge to Grade 11 and 12 secondary school statistics teachers. Though pedagogical content knowledge (PCK) is increasingly being recognized as an essential component in understanding quality teaching and in assessing the teaching of qualified teachers, it is particularly important as it enables us to conceptualise the missing link between knowing something for oneself and being able to enable others to know it (Shulman 1986:9).

**Rationale for PCK as the knowledge base for statistics teachers**

High quality teacher education and development are crucial to improving the quality of teachers and teaching so as to improve educational delivery in South Africa. Teachers make use of pedagogical content knowledge (PCK) to enable them to teach particular content such as bivariate data in statistics, in ways that promote understanding. In his presidential address to the American Educational Research Association, Shulman (1986) coined the term pedagogical content knowledge as a ‘missing paradigm’. He presented pedagogical content knowledge as a specific form of knowledge for teaching which refers to the transformation of subject matter knowledge in the context of facilitating student understanding. Teachers need this type of knowledge so that they are able to structure the content of their lessons, to choose or develop specific representations or analogies, to understand and anticipate particular preconceptions or learning difficulties of their students (Shulman, 1986:7). Rowan, Schilling, Ball & Miller (2001:2) also present a strong case for the existence of pedagogical content knowledge as a separate and unique domain of knowledge for teachers. They refer to pedagogical content knowledge as building upon but is different from teachers’ subject matter knowledge or knowledge of general principles of pedagogy.

The continued interest in pedagogical content knowledge as a knowledge base for teacher preparation has produced a need for a conceptual framework upon which future professional development for statistics teachers can be based. The focus of the pedagogical content knowledge framework proposed in this paper was therefore to integrate teachers’ knowledge that includes error pattern analysis, their knowledge of their students as learners, their ability to plan and prepare, and their ability to use student responses to devise teaching intervention. In the light of the above challenges a detailed design of a pedagogical content knowledge framework that guides the development of pedagogical content knowledge for secondary school statistics teachers during professional development was designed.

**Models of statistics teacher development**

Currently, there are few models for statistics teacher development. For example in Pfannkuch (2005)’s statistical model, he describes three performance levels used in New Zealand, namely achievement, merit and excellence. An assessment model for improving students learning of statistics was also developed by Rumsey Garfield Chance and delMas in 2002.
Rumsey et al.’s statistics model considers an assessment framework based on three learning outcomes which are literacy, reasoning and thinking. However, these and other identified models fail to accurately address and outline the role of PCK in the teaching and learning of statistics.

Teacher knowledge frameworks from the mathematics education domain are also inadequate for examining teacher knowledge for statistics because of the differences between statistics and mathematics. Furthermore, mathematics education lacks studies that have developed, validated and published measures to assess many programs designed to improve teacher knowledge and also how this knowledge relates to student achievement (Hill, Schilling, and Ball 2004).

Methodology
The design of the PCK framework using bivariate data was achieved through development research. It provided a process by which the researcher gets insight from literature and personal experience to create a product by designing, testing and revising several prototypes (van den Akker, 1999:5). The insights that guided the design of the pedagogical content knowledge framework were the conceptual framework by Shulman (1987) himself, development models from Carpenter and Romberg (2004) and Lerman (1991), pedagogical content knowledge taxonomies from Veal and McKinster (2008), pedagogical content knowledge representations and pedagogical and professional-experience Repertoires (PaP-eRs) by Loghran, Mulhall and Berry (2003), literature on reflective practice from Schoen (1999) and Gravemeijer, (1994, 1999).

Aligning the pedagogical content knowledge framework to pedagogical content knowledge

Insights that guided the design of the pedagogical content knowledge framework
The extensive literature on the different interpretations of pedagogical content knowledge gave a very interesting beginning to integrating and intertwining of the pedagogical content knowledge requirements. Loghran, Mulhall and Berry (2003) started with embracing the knowledge of content and students plus the knowledge of content and teaching which make up the PCK. The alignment of the PCK framework to PCK was also partly adapted from Loghran et al (2003)’s two different but complementary formats, the Content Representations (CoRe), which are an overview of the particular content taught when teaching a topic, and Pedagogical and Professional-experience Repertoires (PaP-eRs), an account of the practice intended to illuminate aspects of the CoRe in a particular classroom context. The representations refer to the teaching of a particular topic, bivariate data in this case, to a group of students. Taken as a whole, Loghran et al (2003)’s complementary formats provided the link of the how, why and what of the content to be taught to the students who are to learn that content. A list of pedagogical content knowledge attributes were also generated from Loghran, Mulhall and Berry (2003)’s representations. Pedagogical content knowledge attributes based upon the various attributes and characteristics of pedagogical content knowledge were presented for bi-variate data in the following manner.
Diagram 1: The process of developing the PCK framework

1. A list of all previously described pedagogical content knowledge attributes was generated from Loghran, Mulhall and Berry (2003)’s representations.

2. From this list the most prevalent attributes were determined Veal & MaKinster’s (2008) taxonomies were also adapted for the development of the PCK framework. The general taxonomy of PCK classifies different types of pedagogical content knowledge previously mentioned in the literature and presents an additional category of PCK that provided a broader foundation for future research. The categories include general PCK, domain-specific PCK and topic-specific PCK. These differences legitimate the need for developing topic-specific PCK as an instructional paradigm for teachers (Veal, 2008). Restructuring and
renaming these categories of pedagogical content knowledge serves to clarify the use of PCK in educational research. The three most predominant and recurring characteristics in these taxonomies were knowledge of the students, knowledge of content, and knowledge of instructional strategies (pedagogy). One significant aspect of the taxonomy is its PCK Attributes. Veal and MaKinster (2008) produced taxonomies for pedagogical content knowledge that contributed to an understanding of the attributes that were considered to be most important in the development of pedagogical content knowledge for the teachers of statistics. One important attribute teachers need in developing PCK is a strong and thorough knowledge of their students. Only after a teacher understands or realizes the importance of the student component of teaching, can the other attributes of pedagogical content knowledge be learned or developed. Another significant aspect of the taxonomy of PCK attributes is its less recognition of pedagogical knowledge. The knowledge of the student component has more significance compared to pedagogical knowledge.

Carpenter and Romberg (2004) produced a book with the title Powerful Practices in mathematics (statistics included) and science (Research- Based practices for teaching and learning). This book is based on the research of the National Centre for Improving Student Learning and Achievement in Mathematics (NCISLA) and was dedicated to the teachers and professional development of teachers who serve the nation’s school children. The centre’s work is yielding new visions for student achievement and professional development programs that strengthen teachers’ content knowledge, knowledge of students and in-class practices. It shows instruction that develops understanding of mathematics and science, statistics included by engaging students in the practices of modelling generalization, and justification. This vision of powerful practices is consistent with the most prominent recommendations for reforming mathematics and science in South Africa. In Principle and Standards for School Mathematics and the National Council of Teachers of Mathematics (2000:67) recommended that: “Instructional programs from pre-kindergarten through grade 12 should enable all students to …use representations to model and interpret physical, social and mathematical phenomena. The National Research Council (1996:104) identified evidence, models and explanation as unifying concepts and processes that provide students with powerful ideas to help them understand the natural world. The term modelling according to Tall (1991: 34) refers to finding a mathematical representation for a non-mathematical object or process. There are four basic types of models: models that “look like”, models that “function like”, descriptive models, explanatory or causal models (Carpenter and Romberg (2004:6). This study will use descriptive models to illustrate generalization and justification in statistics.

Lerman (1994)’s critical incidence also made a major contribution to the design of the PCK framework. Lerman (1994) was interested in the complexity and richness of classroom interactions out of which he believed many research questions would originate. Lerman (1994) described critical incidents as ones that could provide insight into classroom learning and the role of the teacher, challenge our opinions, beliefs and notions of what learning and teaching mathematics are about, as well as offer a kind of shock or surprise to the observer or participant. In the light of this, critical incidence can be conceived from teaching aspects, because the incidents might invoke the conflicts and challenges of practice teachers’ beliefs and values, as well as their thinking about professional identities from teacher’s stand to make the best teaching decisions. For critical incidence, anecdotes that elicit a reaction of surprise, and realisation that there may well be something important in the incident from the point of view of the learning of the teacher are initiated. Identifying critical incidence and
engaging in a program of immediate correction is a rich way of learning about one’s teaching and can be used throughout one’s professional teaching life to continue learning.

The Learning environment which was the problem centred approach and the educational setting was selected as the vehicles to drive the design and implementation of the developmental study as they encompassed all aspects of the learning trajectory. The framing of teachers’ PCK has been influenced by constructivist perspectives of learning through the problem centred approach. The implication for this is that teaching for understanding entails teachers developing knowledge about statistics and learners that enable them to make: (1) curricular decisions; and, (2) instructional decisions.

The educational setting
The educational setting set the tone within the pedagogical content knowledge framework, the easy and correct flow of the processes, and the relationship of all activities within the framework. Key items that embodied the main stages in the framework were identified by means of a prior coding system. The coding system reflected the relevant aspects of the intended learning process as specified in the stage plan and was based on the conceptual analysis of pedagogical content knowledge. The link between the purposes and outcomes in the five stages of the pedagogical content knowledge framework were guaranteed through reflection. The educational setting further involves the assessment of the starting level of understanding, the end goal and the development of a chain of bi-variate data activities that bring about a movement towards that goal. The activities in this setting are designed to foster productive mental activities by the teachers, and are accompanied by the designer’s description of why the instructional activity is supposed to work and what kind of mental development is expected to be elicited. This sequence of activities, motivations and expectations makes explicit the learning process in terms of the cognitive development. After a field test the stages were always adapted and changed. These changes, based on the experiences and reflections during the facilitation, start the next research cycle. Key items in the stages guided facilitations, discussions and observations.

Adapting cycles into the design of the framework
The integration of the work from Schoen (1999) and Gravemeijer (1994, 1999)’s development research cyclic process provides insight into the reflective practitioner model of reflection in action. The cyclic character of the design/development research, consists of research cycles in which thought experiments and teaching experiments alternate. The cycles lead to a cumulative effect of small steps, in which teaching experiments provide ‘feed-forward’ for the next thought experiments and teaching experiments (Gravemeijer, 1994, 1999). A macro-cycle of design research consists of three phases: the preliminary design phase(Diagnosing and planning action), the teaching experiment phase(taking action), and the phase of retrospective analysis(evaluating action). In the last-mentioned phase, the reflection captures the development of the insights of the researcher. As a result, new theories or new hypotheses or new instructional activities emerge, that form the feed-forward for the next research cycle that may have a different character, according to new insights and hypotheses. The Reflective Practitioner Model is therefore essentially an approach to decision-making and problem solving. Schön(1983) found that when effective practitioners were faced with a problem in their practice, they worked through it instinctively and, drawing on previous similar experiences, they tried and tested out various possible solutions until they resolved the issue. The practitioner allows himself to experience surprise, puzzlement, or confusion in a situation which he finds uncertain or unique.
The process of the thinking was reported, to ensure the tractability of this development for others. An illustration of this thinking was adapted in the following cycle diagram.

**Diagram 2: The Cycles**

![Diagram 2: The Cycles](image)

**Description of the five stages in the PCK framework**

**Introduction**

The five stages of the PCK framework are previous/present knowledge, bringing teachers into context, statistication, realistic/case based problem posing, assessment and error pattern analysis. The five stages were strictly adapted to the needs of PCK in a problem-centred approach and each stage was designed and analysed uniquely. Each stage lasted one week and the series took place over five spaced out weeks. They lasted one week and were to be carried out for five spaced out weeks. A facilitation/teaching plan was uniquely prepared for each stage, accompanied by instructional activities. During the design phase, products of the framework stages were presented to colleagues, teachers and a workshop. This led to feedback that forced the researcher to be explicit about goals and aims of the pedagogical content knowledge framework, and it provided opportunities for improving the PCK framework.

**Stage 1: Previous/present knowledge**

The researcher sets the stage for learning by finding out what teachers already know, and then connect new ideas to teachers’ existing knowledge base. Using a variety of instructional strategies, the researcher guides teachers from the known to the unknown, from familiar territory to new concepts. Cues, questions, and advance organizers are among the strategies that are used to set the stage for learning. These strategies help teachers focus on what they are about to learn. Classroom and non-classroom experiences, relevant to the intended objectives were achieved through organized in groups activities. Facilitation approaches that optimize learning are those that capture and hold learners’ attention throughout the facilitation. Such approaches also relate new content, skills, and abilities to what is already familiar to the learners. An important point in applying this stage of the framework is that it is often difficult to assess a single concept in isolation of other concepts and skills. For example it may not be possible to assess understanding of bivariate data without understanding the concepts of direct and indirect variation and the concept of linear relationships.

**Stage 2: Bringing teachers into context**
Teachers are engaged in the practices of modelling, generalization, and justification through the availability of already made graphs that need to be analyzed. They learn to pose questions, invent models to address their questions, revise their models in the light of data and go on to pose new and more profound questions. Rich examples of what modelling can yield in classrooms can emerge from this work. This also section emphasizes the relationship between the abstractness of bivariate data and its relationship to the real world phenomena. Teachers were provided with direct experiences of household and time series data so that the subject of the inquiry was concretely visible to them.

**Stage 3: Statisticatization**
The word Statisticatization is a borrowed word from mathematization by Freudenthal (1991). Statistication in this study, in a broad sense entails organizing and playing around with data from statistics as a subject, data from other subjects in the curriculum and data from the real world. Symbolizing, emerge in the process of organizing the available data. It is the organizing activity itself that is central to its conception. Strategies within these characteristics and process include generalizing, justifying modeling and then symbolizing (developing standard procedures and notations). Viewed from this angle, statisticatizing data from statistics and statisticatizing data from reality share the same characteristics. Moreover, statisticatizing data from reality also familiarizes the students with a mathematical approach to everyday-life situations. We may also refer here to the statistical activity of `looking for problems’ (which was mentioned by Freudenthal) which implies a statistical attitude that encompasses knowledge of the possibilities and the limitations of a statistical approach, i.e. knowing when a statistical approach is appropriate and when it is not.

**Stage 4: Realistic/case based problem posing**
This stage provided bivariate data experiences that encouraged exploration by placing the teachers into the researcher’s shoes. Each teacher is also given a chance to make decisions through:
- Reading data from the dot plot representation.
- Interpreting the dot plots based on previous knowledge from mathematics.
- Making predictions based on these representations.
Teachers are led to see that there are often different ways to solve a statistical problem, and recognizing that people may come to different conclusions based on the same data if they have different assumptions and may use different methods of analysis.

**Stage 5: Assessment and error pattern analysis**
Case based problems of bi-variate data were posed at this stage of the framework as they were the key to exploration, reflection and assessment and provided a deep and thorough understanding of the topic. People live in a world where ideas are changing fast and therefore being able to facilitate problems that are case based can bridge this gap. This stage put the teachers into four roles:
- As a teacher to decide what to teach, extract the big ideas, create purposes and outcomes and then produce a teaching plan on how to facilitate this lesson.
- As a student, to respond and prepare a memo as he or she would have liked his or her students to do.
- As a reflexive reflector using, Schoen (1999) and Gravemeijer (1994, 1999)’s ideas in the cycle, to find out about the nature of their students by filling in an already prepared rubric.
As an item writer (examination setter and analyser), to decide on what type of questions could be derived from the given collected data.

Authentic assessment is applied and is a method of obtaining information about students' understanding (e.g. error pattern analysis) in a context that reflects realistic situations, and that challenges students to use what they have learned in class in an authentic context (Archbald and Newmann 1988). This reflected Shulman’s (1987b) concern that, knowledge of learners and their characteristics, as well as teachers levels of content knowledge must be addressed if the pedagogic content knowledge is to be useful and meaningful.

Freudenthal’s cycle/Reflection
At the end of each stage in the pedagogical content knowledge framework, reflection, consciously or unconsciously was an important aspect of the development. Teachers were required to explain and justify their methods and understandings to each other. Explaining their methods to one another served the important purpose to induce teachers to reflect upon their methods, upon what they had done to solve problems and to perform calculations. What is involved in this case, is not about particular methods, but about attitudes towards teaching. It implies an awareness of the learners and the learners’ world.

Results
Using developmental research, a pedagogical content knowledge framework was constructed. The Pedagogical Content Knowledge framework was constructed so as to integrate all the issues of pedagogical content knowledge.

Diagram 3: The Pedagogical Content Knowledge framework.

<table>
<thead>
<tr>
<th>Stages of the PCK framework</th>
<th>Outcomes (Key learnings within the stages)</th>
<th>How to achieve the key learnings (Organised Activities: Appendix 1)</th>
</tr>
</thead>
</table>
| 1. Previous/present knowledge | - Exposure to previous and present knowledge that is related to data and bivariate data.  
- Provision of an in-depth understanding of types of data.  
- Exposure to statistical language that involves bivariate data and to the interrelationship between sections in statistics and mathematics.  
- Group presentations on flipcharts.  
- Teachers’ individual reflection on the day’s facilitation. | - Videos are shown to teachers to expose them to present and previous knowledge related to data and bivariate data.  
- Exposure to a flow chart that unpacks data followed by an activity to complete the flow chart.  
- Diagrams are drawn that expose teachers to statistical language that engage bivariate data.  
- Teachers get poster activities that allow the discussion of data in general (types, collection and representation of data). Teachers identify direct and indirect relationships  
- Group presentations of solutions and areas of concern are recorded and discussed.  
- Teachers get a reflection activity to do individually and for discussion and recording in the next lesson. |
| 2. Bringing teachers into context | -Familiarising teachers with statistical language and processes.  
- Making bivariate data available for informal discussions and analysis Representation.  
- Realistic data being made available.  
- Introduction to bivariate data through the media (language and terms and key words to be used).  
- Applying the product moment correlation coefficient (-1 to 1).  
- Group presentations using flipcharts. | -Teachers analyse and discuss data informally (simply by looking at it) or using methods from previous knowledge  
- Teachers are given (or draw and model – i.e., straight line, quadratic, exponential etc.) graphs of bivariate data before undertaking in-depth analysis.  
- Teachers are provided with newspapers, books, magazines, etc. to identify, discuss and analyse the bivariate data through guided questions.  
- Realistic data (household and time series data) is made available.  
- Teachers solve bivariate data problems in groups and hold informal decisions based on scatter plots produced using the correlation coefficient. (They discuss the need for a relevant measure and range like the product moment correlation coefficient (-1 to 1) and lines of best fit).  
- Group presentations of solutions and areas of concern are recorded and discussed. |
|---|---|---|
| 3. Modeling | -Making relevant tasks and activities (that involve using bivariate data to solve) available to teachers.  
- Employing meta-cognition (thinking about thinking) on statistical processes in bivariate data  
- Deciding what to do with given bi-variates (using lines of best fit/Trend lines and Pearson’s Correlation coefficient) data in order to analyse data in depth for appropriate use.  
- Exploring low level analysis of simple data.  
- Group presentations using flipcharts. | -Teachers are given or draw graphs and model them using previous knowledge of graphs and curves (i.e. straight line, quadratic, exponential etc).  
- Teachers are given bivariate datasets and respond to needs as per questions.  
- Group presentations of solutions and areas of concern are discussed. |
| 4. Realistic/ Case-based problem posing | - Putting teachers into the statistician’s shoes  
- Empowering teachers with authority as a teachers of statistics  
- Group presentations on flipcharts. | - A problem in bivariate data from the health researchers is analysed so that it can be used for the public good  
- A problem in bivariate data in the form of a rubric intended to be used for hiring a statistics teacher for the school is |
- Hearing of teachers’ individual responses to reflection in part three.

- The recording and discussion of group presentations of solutions and areas of concern. Teachers get a reflection activity to do individually and for discussion and recording in the next lesson.

5. Assessment and error pattern analysis

Preparation teachers to teach with PCK by putting teachers into a classroom situation.

- Preparing teachers to know their students by putting teachers into the student’s shoes.

- Providing teachers with relevant tasks and activities that involve bivariate data for solution

- Meta-cognition (thinking about thinking) on statistical processes in bivariate data

- Assessment of the pedagogical content knowledge development

- Delivery of group presentations on flipcharts

- Deciding what to do with given bivariate (Using lines of best fit/Trend lines and Pearson’s Correlation coefficient) data in order to analyze data in-depth for appropriate use.

- A bivariate data task from a past examination paper is given to the teachers to determine how they would plan to teach in order to achieve objectives of responding successfully to their suggested objectives.

- A rubric encourages teachers to clear out Big Ideas that must come out of the teaching of their lessons/s before planning to teach or facilitate a section of statistics. (Note the need for high-level content.)

- Teachers respond to a section of the task which is initiating ideas of how students think or are likely to think in a particular subject area such as bivariate data.

- A rubric/table is provided to be filled in. It assesses the understanding and the change in a teacher with PCK.

- Group presentations of solutions and areas of concern are recorded and discussed.

**Recommendations and conclusion**

**Rationale for using the PCK framework**

The pedagogical content knowledge framework is an appropriate framework for the design of teachers’ education programs (Gess-Newsome & Lederman, 1999). Professional development focusing on pedagogical content knowledge should include the theoretical underpinnings of content and their translation of it into teaching. The goal for the design of the pedagogical content knowledge framework is based on the need to use it to anchor preliminary discussions about the makeup of a model for statistics teacher preparation and to serve the uniqueness of pedagogical content knowledge. It can also be used as a foundation for future professional development of secondary school teachers of statistics and therefore provide a model for statistics teacher preparation. The pedagogical content knowledge framework elaborates on the processes by which pedagogical content knowledge is
developed by its ability to guide the development of PCK through a very intensive educational setting.

The PCK framework highlighted the uniqueness of pedagogical content knowledge through focusing on developing a topic-specific PCK for statistics teachers. By focusing on topic-specific examples, secondary school statistics teachers can focus and develop specific strategies that translate to the effective use of exemplary models of statistics teaching within topics that can later be transferred to another topic or domain. For example, secondary school statistics education programs could focus on developing topic-specific PCK to prospective teachers. Many prospective statistics teachers might know their content well, but they may not have learned how to transform or translate that knowledge into meaningful units for instruction. The effective use of exemplary models of statistics teaching within topics that can later be transferred to another topic or domain is important. The model then further allows the integration of technicalities and complexities of the theory and practice of teaching statistics using pedagogical content knowledge.

Furthermore the pedagogical content knowledge framework helped teachers to be reflective of their instructional practice in ways that can improve the teaching of statistics concepts. Reflective thinking with or without colleagues encourages teachers to better their statistics instruction and to accept the challenges of teaching with humility. This framework brings together learning outcomes, instruction and assessment which have the potential to positively influence the way teachers or students learn statistics. The framework requires advance planning, and success is likely to be achieved only after repeated consistent application. The information gathered was found to be easily adaptable for the decisions on the design of the framework as well as the later analysis of the whole development of pedagogical content knowledge. By focusing on a specific statistics topic the pedagogical content knowledge framework focused on developing specific strategies. These strategies can be applied to other topics and domains of statistics based upon the curriculum backgrounds.

This paper showed that a commitment to sustained, focused professional development that addresses teachers understanding of statistics knowledge of how students learn important ideas and practices, and knowledge of instructional practices that support that learning is critical to supporting meaningful reform in the teaching of statistics. Through the PCK framework developers would be better positioned to plan, implement and access ways to improve teachers understanding of the subject they teach. This paper is intended to stimulate national and cross-national dialogue among policy makers and educators regarding programs and curricular and, in this way, will improve preparation and practice in the teaching of statistics in secondary school statistics. In conclusion, more developments using this framework must be carried out in order to improve the effectiveness of the model. Such developments will enable teachers to use this model for the teaching of statistics in their classrooms and also when they meet for communities of practice. As with many other models of teacher knowledge, this framework has limitations with regard to the indistinct boundaries among the various categories of PCK.

References
Teachers’ reflections on nonstandard students’ work

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Abstract

One of the tasks of teaching (Ball, Thames, & Phelps, 2008) concerns the work of interpreting student error and evaluating alternative algorithms used by students. Teachers’ abilities to understand nonstandard student work affects their instructional decisions, the explanations they provide in the classroom, the way they guide their students, and how they conduct mathematical discussions. However, their knowledge or their perceptions of the knowledge may not correspond to the actual level of knowledge that will support flexibility and fluency in a mathematics classroom. In this paper, we focus on Norwegian and Portuguese teachers’ reflections when trying to give sense to students’ use of nonstandard subtraction algorithms and of the mathematics imbedded in such. By discussing teachers’ mathematical knowledge associated with these situations and revealed in their reflections, we can perceive the difficulties teachers have in making sense of students’ solutions that differ from those most commonly reached.

Introduction

Inspired by Shulman’s (1987) ideas about subject matter knowledge and pedagogical content knowledge, Ball and colleagues at the University of Michigan have developed a conceptualization of math teachers’ knowledge called Mathematical Knowledge for Teaching (MKT). They describe MKT as the “mathematical knowledge, skills, habits of mind, and insight” used to carry out the work of teaching mathematics (Ball, et al., 2008). In part of their work, they focus on the development of an instrument¹ intended to measure teachers’ MKT (Ball et al., 2008; Hill, Sleep, Lewis, & Ball, 2007).

Scholars around the world have shown interest in the MKT conceptualization and in the MKT measurement instrument, and MKT measures have been adapted and used in several countries (e.g. Indonesia: Ng, 2012; Ireland: Delaney, Ball, Hill, Schilling, & Zopf, 2008; and Norway: Fauskanger, Jakobsen, Mosvold, & Bjuland, 2012). In Norway, a complete form² with thirty items from the Learning Mathematics for Teaching (LMT) project (e.g. Learning Mathematics for Teaching, 2011) at the University of Michigan were translated and adapted for use among Norwegian teachers (Mosvold, Fauskanger, Jakobsen, & Melhus, 2009). The primary purpose of such a study was to see if the MKT measure could give valuable information about Norwegian teachers’ knowledge, which might then contribute to the design/conceptualization of suitable professional development (PD) courses for teachers. Another approach was chosen in Portugal, where conceptualization features of the MKT model and the fundamental ideas in which the items were grounded have been used for discussing and reflecting on classroom practices and/or prospective teachers’ knowledge. This was done by accessing and discussing teachers’ knowledge, its critical features, and what promotes or limits its development—ultimately aimed to design PD programs that

¹ This is composed by a set of items (questions) in which the teachers have to select the correct answer for each situation proposed from a set of given answers. For more information on these items see Hill, Schilling, and Ball (2004), and Learning Mathematics for Teaching, (2011).
² Elementary form A, MSP_A04.
enable the development of teachers’ MKT (e.g., Caseiro & Ribeiro, 2012; Ribeiro & Carrillo, 2011).

Besides measuring teachers’ knowledge, we perceive the items (both from the LMT project or others grounded in the same ideas) as a privileged starting point for reflection and discussion on the MKT involved in approaching different topics and situations. As part of adapting MKT measures for use in Norway, seven focus group interviews were held with fifteen teachers who had participated in the pilot study using the MKT measures (Wilson, 1998). In these interviews, teachers discussed and reflected on the items they had answered in terms of format, content and relevance. One portion of the work done in Portugal concerned early year future teachers’ MKT, focusing on how they acquire it, how it evolves, and what factors (in terms of learning opportunities) influence such evolution. Fifty-three trainee teachers answered a questionnaire within the framework of the LMT items, but with open questions. Both of these approaches provide valuable information about teaching, MKT, and insights on the knowledge involved in improving teaching. Because such knowledge can be taught (Hill & Ball, 2004), this can help mathematics educators to improve their training programs (both in terms of conceptualization and implementation), and ultimately to become more effective and more conscientious of their MKT.

In this paper we focus on discussions and reflections stemming from situations in which trainees and qualified teachers were asked to make sense of nonstandard students’ work (after they have solved the situation themselves), and in particular in connection with students answering problems by using nonstandard algorithms. We do not give a full report about these two separate projects, but rather report from observations made independently, which together have developed a momentum and consensus of their own. By discussing and reflecting on what we are learning about teachers’ MKT, we hope to contribute to the discussion about how to improve and develop training focused on teachers’ MKT, both with trainees in teacher education and with qualified teachers in professional development programs. With this goal, we address the following question: What can be learned from teachers’ reflections on situations in which they struggle to understand nonstandard students’ work in order to conceptualize ways of improving teachers’ MKT?

Theoretical framework
Teachers play a key role in students’ learning at all educational levels (Rowan, Correnti, & Miller, 2002). Several studies have documented that teachers have a greater impact than any other factor (e.g. class size, school size, and school system) when it comes to student achievement (Nye, Konstantopoulos, & Hedges, 2004). Despite these findings, we still know little about what constitutes effective teaching, which specific tasks of teaching teachers find hard or easy, and what can be done to improve teaching and learning. What we do know is that researchers have found that teachers’ mathematical knowledge and experience, broadly construed, are not consistently associated with greater student learning (Begle, 1972, 1979; Ball, Lubienski, & Mewborn, 2001; National Mathematics Advisory Panel, 2008). We see, however, the mathematical knowledge associated with achievement gains for students is specifically related to the work of teaching and the mathematical tasks that constitute that work (for a review see Hill, Rowan and Ball, 2005). It is this evidence that led Ball and Bass (2003) to develop a theory of mathematical knowledge for teaching, where the “for teaching,” in this context, means a practice-based characterization. Ball, Thames, and Phelps (2008, p. 399) define MKT to be mathematical knowledge “entailed by teaching”—in other words, mathematical knowledge implicated by the demands of teaching and central to performing the recurrent tasks of teaching mathematics to students. From our view, the
insistence that claims about what teachers ought to know be warranted in practice brings a direct challenge to intuitive notions about what would be “good for” teachers.

**Mathematical knowledge for teaching**

Grounded in Shulman’s (1987) categories of subject matter knowledge (SMK) and pedagogical content knowledge (PCK), Ball et al. (2008) introduced a model to allow a better understanding of the MKT conceptualization, still under development, with some refinements and new subgroups regarding teachers’ knowledge (Figure 1). Such conceptualization emerged from analysing classroom teaching from a mathematical perspective. They have suggested dividing SMK and PCK into three distinct sub-domains, and have indicated that MKT is a multidimensional construct.

In this paper we only discuss the sub-domains of SMK, as our approach focuses on teachers’ reflections about their MKT when giving sense to nonstandard students’ answers. In this sense, we focus on the mathematical knowledge involved in sustainable practice related to knowing how to perform an operation (through an algorithm), and the knowledge that would allow teachers to go beyond knowing how to perform, and thus give sense of other answers and/or explain their possible reasoning.

![Figure 1. Domains of Mathematical Knowledge for Teaching (Ball et al., 2008, p 403)](image)

Within SMK is included common content knowledge (CCK), which corresponds to the sort of general mathematical knowledge that is used by people in their life and work: “schoolchild” math; specialized content knowledge (SCK), which concerns the knowledge that allows the teacher to know how to make the subject understandable to others, and which is a crucial part of the knowledge needed by teachers to do the mathematical work of teaching; and a provisional category, horizon content knowledge (HCK) that describes how “mathematical topics are related over the span of mathematics included in the curriculum” (Ball et al., 2008, p. 403). In other words, content knowledge needs to be complemented by an understanding of how to make the given content accessible to students, and this includes knowing where and why students might encounter difficulties (Ribeiro & Carrillo, 2011).
SCK is a different type of mathematical knowledge than CCK. While CCK is about being able to solve mathematical problems correctly, SCK is the mathematical knowledge unique for teaching, which complements CCK. It concerns the knowledge that allows the teacher to engage in particular teaching tasks, including how to accurately represent mathematical ideas, provide mathematical explanations for common rules and procedure, and examine and understand unusual solution methods to problems (Ball et al., 2005).

This can perhaps best be illustrated by a subtraction computation problem: 51-17. Most of us will use some kind of algorithm to produce the answer. But which algorithm is common can vary from country to country, and sometimes even within the same country.

In Figure 2, a) is the algorithm most commonly used in Norway, while b) shows the typical algorithm used in Portugal. Teachers must be able to perform this calculation, whether by using an algorithm or not, and to know when the result is (in) correct. This is generally common knowledge among other professions outside teaching and mathematical fields (in this case, the algorithm involves a very basic mathematical knowledge, typically at the level of primary school pupils). However, being able to interpret students’ use of nonstandard algorithms involves a different type of mathematical knowledge that is not part of CCK. The answer is correct, as is the thinking used in solving the problem in both ways, and the procedures can also be generalized, but they involve two different approaches to working with numbers. At first sight, the reasoning might not be obvious for a reader that is not familiar with the algorithm. A teacher should be able to figure out such nonstandard work and determine whether the thinking is mathematically correct for the problem, and whether the approach used would work in general (Ball et al., 2008). This is an example that teachers need knowledge (here related to subtraction) that is not part of common content knowledge and not necessarily needed in other professions. Understanding nonstandard student work is one example of a task of teaching and is considered as part of teachers SCK. Besides this specificity, teachers need to know when results are not correct, and to identify the errors, as mentioned previously, which are seen as CCK. Besides being able to give sense to nonstandard students’ solutions, teachers must be in possession of knowledge that allows them to understand the mathematical motives that lead to any errors and to not only identify them, but be able to correct them and promote in students a true understanding of the mathematics embedded in the errors and the correct answer (SCK).

This specificity of teachers’ mathematical knowledge when compared with that of any other professional who uses mathematics from the perspective of knowing how to do, has a direct relationship with the kind of tasks teachers are expected to develop in teaching. These tasks can be called “tasks of teaching” (Ball et al., 2008) and the work “involves an uncanny kind of unpacking of mathematics that is not needed—or even desirable—in settings other than teaching” (Ball et al, 2008, p. 400). These mathematical tasks of teaching comprise, amongst
others: presenting mathematical ideas; responding to students‘ “why” questions; linking representations to underlying ideas and to other representations; choosing and developing useable definitions; asking productive mathematical questions.

One factor that led us to the selection of the conceptualization of MKT over other conceptualizations of teachers‘ knowledge is a response to traditions trying to address documented weaknesses in teachers‘ content knowledge by increasing requirements for more advanced mathematical study in teachers‘ education and professional development. Our selection is also a response to the many studies showing that teachers‘ advanced coursework in mathematics has no positive effect on their students‘ learning (e.g., Eisenberg, 1977). With our approach, besides identifying teachers‘ mathematical and critical skills, we aim to get a deeper understanding of their motives in order to allow discussion and to conceptualize ways of improving teachers‘ training (both initial and continuous).

**Contexts and methods**

Here we will report on some data gathered from the focus group interviews with Norwegian teachers. For the sake of validating and testing out the U.S. developed MKT measures (Learning Mathematics for Teaching, 2011), one hundred and forty-two teachers from seventeen university practice schools participated in a pilot study (Fauskanger, Jakobsen, Mosvold, & Bjuland, 2012). From this sample, seven schools were selected and seven semi-structured focus group interviews were conducted with fifteen teachers after the participating teachers had individually answered all the items. Of these, six teachers worked in primary and middle schools (six to twelve years old in Norway), and nine teachers worked at lower secondary schools (thirteen to fifteen years old). As part of the focus group interviews, the teachers reflected on and discussed items. The interviews were audio recorded and transcribed, using Törner, Rolka, Rösken and Sriraman‘s (2010) perspective. For the purpose of this article, we analyzed the transcriptions according to how the teachers commented on each individual item on issues related to the research question. Because the LMT items have not yet been released, we can‘t divulge the actual question presented to teachers, but it involved possible students productions aligned with the two examples presented previously in Figure 2.

Concerning the Portuguese contexts, some questionnaires were applied to prospective early year teachers. These questionnaires were developed from the perspective of the LMT items, but in this case the aim was not to evaluate future teachers‘ knowledge. The goal was to provide open questions, allowing prospective teachers to express their knowledge but also doubts and fears, and to access also their most critical features in terms of MKT. These questionnaires were applied to eighty prospective teachers in the context of a mathematics course, where one of the topics concerned operations and algorithms. The study we present here takes an instrumental case-study approach (Stake, 2005), using data from the two contexts (though the comments from the Portuguese prospective students are mentioned mainly to illustrate the fact that the comments/ reflections from Norwegian teachers were not due to the context they were immersed in, neither in terms of social or cultural context, nor in terms of the nature of the tasks/ items they were supposed to comment upon). We do not focus on the cases themselves, but rather on the information we can obtain from them, which may allow us to deepen the level of understanding of the phenomena under analysis and elaborate on the theorization thereof. As previously mentioned, we will present transcription from focus group interviews in Norway, and use the data from the prospective teachers‘ questionnaires to contrast and/or reinforce the ideas given by the Norwegian teachers.
Reflections on nonstandard students’ answers
Of the thirty LMT items considered and discussed in the Norwegian FGIs, one item addressed the task of teaching of understanding and giving sense to nonstandard student work. This item (Item 10) presented a simple subtraction problem solved correctly by a student in an algorithmic way different from that taught by teachers and commonly used by students in Norway. The nonstandard solution method is similar to the work done in Figure 2b. The item gave the teachers several possible explanations for what the student had done. This item was mentioned in two of the FGIs, in School 2 and School 6. Below is the transcription from the FGIs in School 2 and 6, starting with the discussion between the interviewer (I) and teachers T2A and T2B at School 2:

104. T2A: I had difficulties with [answering] that one. What did you answer?
105. T2B: I actually skipped that [item].
106. T2A: Yes, that was a rather tricky way of doing it. Is it d. that is the correct [answer] or is it…?
107. I: I don’t have the solution with me; was this [item] tricky? Was it because of the calculations, the way it is done, or is there something you don’t recognize?
108. T2B: Yes, you have to interpret… It is kind of like we have to understand what they actually have done, isn’t it?
109. T2A: It is extremely important to understand what they have done, but I’ve never experienced something like this.
110. I: No, you have never seen this error pattern before, or perhaps it is not a pattern, but…
111. T2A: No, exactly like this I have never seen, but I have seen many different ways of doing things, and [I have] found out why they have done like that. But exactly like this, I have never seen before.
112. T2B: But when you are in the classroom…and see the error pattern, then you can ask the kids about what they have done and why…
113. T2A: [murmuring] homework, so I am very strict with…
114. T2B: Yes, and then you get an explanation.
115. T2A: …and…careful about asking what have you done and can you do this in this way, or is it correct?

Figure 3. Extract from transcription of a FGI, School 2

91. T6B: There you have a wonderful example of [an item] where I would have asked [the students]: What have you done, could you show me what you have done?
92. I: Yes.
93. T6B: Instead of me using twenty minutes to try and figure out what on earth they have done
94. I: You would have asked…?
95. T6B: Yes, I missed that as an option.
96. I: Yes.
97. T6B: But I have to reach an answer by guess work.
98. I: This could have been what you got back from written homework…if that was the case…then it would have been difficult to ask, you would have to make a decision about the work… perhaps it would not be possible for you to ask students directly.
99. T6B: Yes, yes….
100. I: That would require that you try to actually understand the student’s thinking, when they suddenly use another approach than what we have learned…
101. T6B: Most likely the answer they gave is correct, and then….it is not easy to know what they have been thinking.

**Figure 4.** Extract from transcription of a FGI School 6

In both of these discussions, the teachers revealed that they didn’t have knowledge other than CCK on this topic (being able to solve the computation and see that the students found the correct answer). Teacher T2B admitted that he skipped that item (105), and T2A also had difficulties (104). Teacher T2B understood that the item is actually about understanding the student’s solution (108), but argued that if this had occurred in a classroom situation, he could ask the student about what he had done and why (112) and felt confident that he would get an explanation (114) without needing to understand the student’s reasoning and the mathematical thinking behind the solution.

T6B offered similar reflections and argued that, instead of spending time trying to understand the work, he would have asked the student (91, 93). Since he doesn’t know the answer and did not show any evidence of possessing the knowledge to make sense of the solution, he concludes that he would have to guess (97). In School 2, however, teacher T2A argues that it is extremely important to understand what students do (109). He also reveals that he has experience of seeing problems solved in many different ways and being able to figure out and understand what students have done (111). Teacher T6B argued that the answer the student reached was probably correct, but because it is not easy to know what the student was thinking (101), he is not sure. He does not even realize that he could have checked the correctness of the answer using an algorithm he was more familiar with.

The written explanation and justification (written in the questionnaire) given by the prospective Portuguese teachers when making sense of Figure 2 a) was of the same nature as the ones given by Norwegian teachers when making sense of 2 b), which was nonstandard to them. The Portuguese teachers’ explanations and justifications can be summarized with the following two answers:

(A): I would not know what the students may have been thinking. I can’t get into his/her head.

(B): The result is correct, the student got the same result as me, so he must have done the same process [traditional algorithm] but then made some kind of confusion when registering the steps.

Besides the evidence of CCK only concerning the possible ways to obtain the result of the operation being present, the prospective teachers assume that there is only one possible way
of getting the correct answer: the one they learned when they were students in primary school.

**Final comments and reflections**

These (prospective) teachers show evidence of gaps in MKT, specifically related to SCK, expressed in the inability to give sense to nonstandard solutions—in this particular case, a nonstandard algorithm (and even to ones which are not that far from the “standard” ones). In practice, they might “fill” such a gap by asking students to “explain what they had done.” Such knowledge (or the lack thereof) may lead teachers to run blindly through a set of given procedures, and to not acknowledge the correctness of alternative algorithms used by students, which may then lead students to assume the teacher’s knowledge (or the lack thereof) as their own.

Practice, and subsequent students’ hypothetical opportunities for learning (Hiebert & Grouws, 2007) are grounded, necessarily, in the knowledge that teachers have (or assume they have) about each topic they are going to teach. Teachers’ knowledge is fundamental in defining each teacher’s core tasks of teaching, how they develop them, and the role of the different elements involved in the teaching/learning process. On the one hand, teachers’ knowledge (or its lack) influences the nature of the tasks teachers prepare for students and the way they are carried out in the classroom (Charalambous, 2008), thus avoiding contingency moments (Rowland, Huckstep, & Thwaites, 2005). A lack of knowledge and flexibility will also limit the richness of the tasks given to students, and perhaps make teachers and students alike fear the “why” questions, as they may not feel confident about answering them in a mathematically correct and understandable way, nor about making sense of the answer and acknowledging what they do and why they do it.

By focusing on this specific task of teaching in two very different contexts, and on the mathematically critical features emerging from it, we get a better understanding of teachers’ MKT that leads them to struggle in the understanding of nonstandard student solutions, which is part of SCK. This illustrates that teaching mathematics is not only about the level of knowing for ourselves (being able to do math, as a user), but also involves other aspects of teacher’s knowledge (for example, SCK). In addition, we can draw attention to and get deeper insights on some of the whys and hows that may be at the basis of teachers’ difficulties in understanding/giving sense to different ways of doing mathematics, and from those insights we are able to focus our efforts where they are most needed when preparing courses or professional development programs aimed at improving teachers’ MKT and teachers’ training in general.

In line with Kazemi and Franke (2004), we also assume that discussing and reflecting on students’ answers (real or hypothetical) might contribute to promoting teachers’ awareness of their own critical skills and lead to an improvement in teachers’ MKT. First, we should work for a better and deeper understanding of the dimensions of teachers’ MKT in all tasks. If we can find out how the different dimensions of MKT relate to and influence each other’s, and how they influence teachers’ reasoning and practice, it will give educators and future educators documentation about what matters in teaching. Then, hopefully, we can change the focus of teachers’ training and teaching practice, ultimately improving students’ learning opportunities and results. Much can be achieved if teachers become aware of the different dimensions of MKT in their own practice. By this we do not mean that the teaching of the MKT domains should be a focus of teaching in the courses, but we assume that the tasks prepared and implemented in teachers’ training should focus on developing those domains,
taking into consideration its specificities, as well as the specificities of the tasks of teaching in which such knowledge might be more easily seen. An awareness about these important aspects of teachers’ knowledge and the effect it has on teaching practice can contribute to a widespread desire and plan to enrich and improve each teacher’s own MKT. This can help in reducing procedural teaching, now far too common in many primary schools (Brocardo & Serrazina, 2008), and instead promote a teaching grounded in an effective understanding of the basic concepts and the mathematical justifications of various procedures and tasks.

This seems to be an area in which there is a need for further research, because one of the core tasks of teaching is to make sense of students’ reasoning and solutions, even the nonstandard ones. This is thus an area in which further training can contribute to deepening teachers’ understanding of the mathematical knowledge in order to teach it well (Ball, Lubienski, & Mewborn, 2001), and the research could contribute examples of mathematical critical situations to be further discussed in training.

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Procedural spectrums: translating qualitative data into visual summaries

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Abstract
In earlier work we introduced the notion of a procedural fluency spectrum as a way of analysing the wide variety of learner responses to an orally administered numeracy interview instrument. One of the conclusions of the earlier article was to interrogate the value of the spectrums by using them to analyse and summarise our data. In this paper we explore the viability of using a procedural fluency spectrum as a means of translating the methods recorded on the qualitative interview records into quantifiable, visual summaries of the learner data at given points in time. By presenting this we wish to contribute methodologically to how qualitative data captured in a numeracy interview might be usefully translated into visually quantifiable summaries of learners proficiency levels. We propose that this may be of value to other researchers working with the Learning Framework in Number or other such assessments or recovery instruments. Our findings suggest that such summaries provide quick visual access to the picture and that different type of outputs generated from this data could provide many different perspectives.

Introduction and context of the study
Kilpatrick, Swafford and Findell’s (2001) strands of mathematical proficiency have been widely used in South African mathematics education circles (Adler, Ball, Krainer, Lin, & Novotna, 2005; Schäfer, 1999; Venkatakrishnan & Graven, 2006). The power of this work is that it provides a rich and elaborated notion of mathematical proficiency – an idealised notion that as teachers we can work towards developing in our learners. We have used Kilpatrick et al’s (2001) strands of mathematical proficiency as a framework for analysing learner responses to an orally administered numeracy instrument. Converting an idealised version of mathematical proficiency into a tool that one might use to support analysis of learner progression requires much effort and in earlier work we have expanded on how we have done this for one strand, namely procedural fluency (Graven & Stott, 2012a). In this paper we share with you further work from a methodological perspective that the first author has done in exploring the viability of using the spectrums generated in our previous work as a means of translating the methods recorded on the qualitative interview records into quantifiable, visual summaries of the learner data at given points in time. We believe that this may be of value to other researchers working with the Wright et al (Wright, Martland, Stafford, & Stanger, 2006) Learning Framework in Number or other such assessments or recovery instruments.

The first author (Debbie) is a full time doctoral fellow and intern in the South African Numeracy Chair researching the nature of student learning within two Grade 3 after-school maths clubs. She is also responsible for the design and setting up of these two clubs. The broader research within this PhD study looks at how learners mathematical proficiency levels evolve in relation to their participation in informal after-school maths clubs and focusses on two critical questions. The first relates to how learners mathematical proficiency levels evolve (if at all) over the period of participation in the maths club and the second on looking at the learning mechanisms that enable this evolving mathematical proficiency. The focus for
this paper is the learners mathematical proficiency data that has been gathered for the first
question and here we focus on the emerging insights and data relating to this question.

The second author, Mellony Graven is the Chair and supervises a number of full and part
time masters and doctoral students. The aims of the SA Numeracy Chair are twofold and
focus on a dialectical relationship between development and research. In development terms
the Chair teams are expected to improve the quality of numeracy teaching at primary level
and to improve learner performance in primary schools by providing quality teacher and
learner focussed activities.

Learner-focused activities within the Chair development work foreground the importance of
numeracy as well as to create a ‘maths is fun’ ethos in schools. Learner after-school maths
clubs are a key aspect of the Chair work and provide a ‘direct learner focused intervention’.
These clubs have been conceptualised and elaborated on in previous work by Graven and
Stott (Graven, 2011; Graven & Stott, 2012b). They provide a field of influence and an
empirical field (for research) that enables a powerful dialectical research and development
cycle that involves working directly with learners rather than via the teachers.

In 2011, we established a pilot after-school club in one of the Chair schools with ten regularly
participating Grade 3 learners which ran over 14 sessions from August to November. The
club focused on strengthening learners’ basic number work, fluency in addition (and number
bonds to 10), place value and problem solving. Additionally we focused on developing more
positive participatory socio-mathematical norms (Cobb, Wood, Yackel, & McNeal, 1992;
Yackel & Cobb, 1996) and mathematical discussion and argumentation through collaborative
work. In the pilot club the methods learners used were captured in the oral interview
instruments and could sometimes be seen on the scripts of the written instruments. However,
our coding of responses in terms of accuracy (i.e. correct or incorrect) failed to reveal if there
was increased flexibility and fluency in the way they answered. Our failure to capture this
key aspect of their learning led to a redesign of instruments for our subsequent clubs. We also
saw the need to consider coding systems that would enable tracking learner movement over
time.

Conceptual framework
The Chair works towards improving numeracy proficiency among learners. The Chair bases
its notion of numeracy proficiency on Kilpatrick et al’s (2001, p116) definition of
mathematical proficiency. This definition comprises five intertwined and interrelated strands:

- Conceptual Understanding – comprehension of mathematical concepts, operations
  and relations
- Procedural Fluency – skill in carrying out procedures flexibly, accurately, efficiently
  and appropriately
- Strategic Competence – ability to formulate, represent, and solve mathematical
  problems
- Adaptive Reasoning – capacity for logical thought, reflection, explanation and
  justification
- Productive Disposition – habitual inclination to see mathematics as sensible, useful,
  and worthwhile, coupled with a belief in diligence and one’s own efficacy.

Although the ideal is for learners in our clubs is to become mathematically proficient in each
of these five strands, we need a way of tracking and seeing how learners actually work
towards this idealised or fully elaborated notion of mathematical proficiency (Graven & Stott, 2012a). The Learning Framework in Number (LFIN) developed by Wright and colleagues (Bobis et al., 2005; Wright, Martland, Stafford, et al., 2006) provides a useful way of doing this. This framework has been used to research and document progress in number learning of five to eight year old students in the first three years of school; as an intervention program that involves intensive teaching of low-attaining students (Wright et al., 1996) and with students of all levels of attainment. The intervention program known as ‘Mathematics Recovery’ (Wright, 2003) has been used extensively by school systems in several countries including the United States and the UK. LFIN and the principles of Mathematics Recovery have provided the basis for our orally administered numeracy instrument (see section below) as well as a way of structuring and reporting on data from these instruments.

The key components of the LFIN are:

a. Strategies for counting and solving simple addition and subtraction tasks
b. Very early place value knowledge, (ability to reason in terms of tens and ones)
c. Facility with forward number word sequences
d. Facility with backward number word sequences
e. Facility with numeral identification
f. Early knowledge of multiplication and division (Wright, 2003)

Each of the key components of the LFIN is elaborated into a progression of up to six levels (or stages). These stages, in order of increasing sophistication, are: emergent, perceptual, figurative, counting-on and counting-back, and facile (Wright, Martland, Stafford, et al., 2006). In a similar way to Kilpatrick et al.’s mathematical proficiency, Wright points out that “while each aspect can be considered from a distinct perspective, it is also important to focus on the inter-relationships of the aspects” (2003 p. 9).

By using the LFIN framework one is able to profile a learner’s mathematical proficiency across the range of the key components. Profiling of learners’ mathematical proficiency in this way forms a basis for planning club activities and interventions that are tailored to each learner’s current levels of proficiency and strategies (Wright, 2003). It also gives us a way of seeing if there is progression from one level (stage) to another, over time.

Whilst our oral interview instrument (see more below) covers a range of Kilpatrick et al’s strands and the LFIN components, the focus in this paper is on the procedural fluency strand and the first component of the LFIN, namely strategies for counting and solving simple addition and subtraction tasks. We exemplify using the same 2 examples from our previous paper.

**Instrument for gathering data on learner mathematical proficiency**

In early 2012 we introduced a new oral interview instrument into the clubs, which is more comprehensive than the instrument used in the pilot. For this instrument we drew on the work of Askew and his team in the *Effective Teachers Of Numeracy* study conducted in England in the nineties (Askew, Brown, Rhodes, Johnson, & Wiliam, 1997). Thanks to their permission and providing the Chair with the instrument we were able to select and adapt various items they used in assessing learners numeracy proficiency. However the work of Bob Wright and his colleagues (Wright, Martland, & Stafford, 2006) on Mathematics Recovery in Australia also provides excellent opportunities and examples of assessment items that enable one to...
gauge learner progress through various stages of numeracy development. This framework (LFIN) has been briefly explained above. The assembled instrument combines questions (sometimes adapted) from both these key works. The instrument is administered to each individual learner in a one-to-one interview lasting between 45 to 60 minutes. This instrument was administered to all Grade 3 club learners in April 2012 and will be administered again in late October or November of 2012.

The emergence of a spectrum
We use examples from our oral interview instrument to illustrate this spectrum of procedural fluency. We also draw on the range of learner responses in order to illuminate the need for the spectrum in assessing learners’ levels of procedural fluency. While we deal with procedural fluency in this paper, as a strand on its own, this should not imply that we see the strand as separate from other strands or that we are falling prey to the false dichotomy often set up between procedural fluency and conceptual understanding.

In Graven and Stott (2012), we illuminate how when coding and analysing this oral interview, an overlap of learner methods/responses as both procedural fluency and conceptual understanding arose. We considered the development of a procedural fluency spectrum to display a range of responses from restricted / constrained procedural fluency towards elaborated and fully flexible fluency. It became evident that as one moved to the upper end of the spectrum where flexibility and efficiency were high, conceptual understanding was increasingly intertwined with procedural fluency and the distinction between these strands became progressively blurred. Indeed the inter-relationship between these strands was progressively more visible at this upper end of the spectrum (Graven & Stott, 2012a).

We also began to reflect on how we might capture the richness of the range of responses in a way that would allow us to notice shifts in responses over time. As we looked at each question, we discovered that each would, in almost all cases be categorised as a question engaging procedural fluency. Taking it a step further, we realised that if the learner answered the question correctly, regardless of the method they used to answer it, we were tempted to say they had achieved procedural fluency. Yet, the method they used may have contradicted the notions of efficiency and fluency, even while they had answered correctly. This struck us as problematic.

Procedural fluency, according to Kilpatrick et al (2001, p. 121) refers to “knowledge of procedures, knowledge of when and how to use them appropriately, and skill in performing them flexibly, accurately, and efficiently“. By categorising a question as procedural fluency and simply marking the learner response to questions as correct or incorrect, meant that we were disregarding several key elements of the strand, namely appropriateness, flexibility and efficiency.

Looking at question 10 part ‘a) add 10 to 92’ from the interview, we found that the learners answered the question using these possible methods, some of which are more efficient or appropriate than others.

Table 1 - Q10 possible methods

<table>
<thead>
<tr>
<th>Possible Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Less efficient ways would be to: draw the sum on paper (e.g. concrete representation of the number by drawing 10 and 92 dots and recounting), or count on 92 from 10 using fingers (or counters)</td>
</tr>
<tr>
<td>• A slightly more efficient way may be to use a standard vertical algorithm such as:</td>
</tr>
</tbody>
</table>

58
More efficient ways would be to count on 10 from 92 in ones or by using fingers.

The most efficient method would be to mentally add 10 to 90 and then add 2 (or 10 to 92 with knowledge of the pattern of adding tens) thereby involving conceptual understanding of commutativity, patterns and place value.

Similarly, it can be seen, that the less efficient methods would become even less efficient ways of answering Question 10 part b and d.

**Question 10: Adding / subtracting with tens**

[Ask orally]

<table>
<thead>
<tr>
<th>Correct?</th>
<th>Note</th>
<th>Given</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Add 10 to 92</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) Add 10 to 294</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) Take 10 away from 50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) Take 10 away from 700</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1 - Question 10 from the interview**

Another example, question 9 from the interview involves the placing of successive strips of dots in each part of the question. For example for part ‘e add another 30 to make 74’ the interviewer will place an additional three strips of ten dots onto the previously laid out strips and ask ‘Now how many dots altogether?’

**Question 9: Counting with incrementing tens**

[Use pink strip cards. Show strip (a) then add others for steps b to e. Ask] How many dots are there altogether?

<table>
<thead>
<tr>
<th>Correct?</th>
<th>Note</th>
<th>Answer &amp; How Answered</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) The ‘four dot’ strip</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) Add a ‘ten dot’ strip to the right</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) Add another 10 to make 24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) Add another 20 to make 44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(e) Add another 30 to make 74</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 2 - Question 9 from the interview**

Again, this could be categorised as a procedural fluency type question, and the learner could be said to be fluent if he/she were to answer the elements correctly. But the issue arises again as to the levels of efficiency and flexibility employed.

**Table 2 - Q9 methods**

- Less efficient ways would be to count the dots each time a new strip is added including the 4 dot strip
- Slightly more efficient ways would be to physically count the first 10 strip in ones or twos and then count each strip as they are laid down

---

3 We are aware that whether the standard algorithm or counting on from 10 is more efficient, depends on each individual learners skill at using these methods and thus aware of the subjectivity we have used in placing them in this list, in this order.
- Slightly more efficient again, would be to physically count the first 10 strip in ones or twos and then mentally add 10 each time a strip is laid down.

- The most efficient method is to mentally count the dots on the 10 strip and then count in groups of 10 e.g. 44 + 30 is 74 (knowing 40 and 30 is 70)

We can also see that the less efficient methods are not really appropriate for working with bigger numbers especially in part (e) and 74 dots. We noted that some learners counted in ones from the beginning each time even to get 74, accurately and correctly. To say they have no procedural fluency would do no justice to the fact that they performed the skill of counting in ones accurately. On the other hand, to give it more value than simply acknowledging a basic procedural skill (of one-to-one counting) would be problematic. Thus we saw the need for a spectrum that indicates that as one moves along the spectrum one is working with increasing levels of cognitive demand, mathematical complexity and levels of abstraction.

Thus we argued (Graven & Stott, 2012a) that at one end of the spectrum we have restricted procedural skill that could be described as rudimentary or constrained, whilst at the other end we have procedural fluency that is elaborated and fully flexible. For any given question, there may be points in between these two end points as illustrated in the examples given above.

A sample spectrum for the task 9 example above could look like this:

![Figure 3 - Q9 spectrum](from Graven & Stott, 2012a p.154)

It should be noted that not all questions in the interview lend themselves to being answered using multiple methods. For example, some of the questions ask learners to identify numerals displayed on cards or to count backwards / forwards from a given number. We shall refer to these as ‘non method questions’. We shall refer to the questions that do allow different methods to be used as ‘method questions’.

Using this same process, we have examined each method question in the interview and have drawn up a spectrum for each based on the range of responses we recorded from the learners.

**Generating visuals from the spectrums**

One aspect of the first author’s doctoral study is to explore how individual learners’ mathematical proficiency levels evolve (if at all) over the period of participation in the after-school maths clubs. This section of the paper reflects how she has built onto our previous work and as such will be narrated in the first person to reduce wordiness.

My doctoral study collects both quantitative and qualitative data for 2 clubs and takes a broad mixed method approach to analysing the data. This approach is in synergy with the types of data collected by the Chair in the other clubs. Much of the data collected using the instrument discussed here is analysed on an on-going basis and is used in a dialectical manner for both research and practice in the clubs and reflects that dialectical nature of research and
development in the Chair. This could be thought of as using ‘concurrent mixed methods’ where one merges quantitative and qualitative data to provide a comprehensive analysis of this particular research problem.

In this section of the paper however, I am concentrating on working with this specific interview data in a quantitative way in order to gain a broader and more visual understanding of club learner’s mathematical proficiency and to drive my awareness of the learners current proficiency at any given point in time.

Data collected in my doctoral study is by and large qualitative, but I still felt a need to have access to quantitative, summarised data. I asked myself whether it is viable to get this type of data from the instrument we are using. Having a strong Information Technology (IT) background, I was also challenged to use my IT skills to see if this information could be generated. I wanted to gain a deeper and richer sense or understanding of this learner evolvement or change by looking at it from multiple perspectives. It struck me that it may be beneficial to my doctoral study to use quantitative analysis for this part of the study as the outputs from this type of analysis can be highly visual, can give a broad overview and can show relationships between data sets. Quantifiable and visual data will allow me to track mathematical proficiency changes over time, will allow me to gain insight into whether individual learners have evolved or not in the time between administration of the instrument. As I run two of the Chair clubs, we may also, in time wish to compare the methods used by learners in different clubs to answer the same questions in the interview.

Another important reason for gathering data from this instrument is to drive the activities that are promoted in the club sessions and therefore to act as a guideline of how the learners approach the solving of different problems. I explore this further below.

**Initial considerations**

From initial analysis it was clear that this instrument yields rich qualitative data and will enable us to tell detailed stories about learners in the clubs. My concern was if there was potential for it to also generate quantitative data outputs so as to inform my on-going work with the learners in the clubs. There were two key requirements for this quantitative data.

Firstly, in line with the requirements of the Chair, I wanted to generate data for each club and for each learner that shows their level of accuracy in answering the questions regardless of method used to allow comparisons over different points in time. Here it was important to see an accuracy score for each child, for each question. Additionally I also wanted to arrive at a score for each component of development as suggested by Wright et al’s (Wright, Martland, Stafford, et al., 2006) Learning Framework in Number (LFIN). Generating this was relatively straightforward and achieved without any problems using a standard spreadsheet and by collating the questions under different LFIN components.

The graphs below show summarised data for all the questions in the oral instrument where the answer is either correct or not, based on allocating a score of ‘1’ for an accurate answer and a score of ‘0’ for an inaccurate one.
Secondly, and more importantly, based on the definition of procedural fluency stated previously (Kilpatrick et al., 2001) I needed to see data for each club and for each learner that revealed whether their methods of answering the questions are efficient, inefficient or somewhere in between. I wanted to be able to see this as an overall indicator for the club and for each individual learner. In addition I wanted to see which questions were being answered more or less efficiently for the club as a whole and for each learner.

Presenting the data in this way not only allows me to track change as a way of addressing my research question but it also allows me to plan activities for the clubs that will promote opportunities for learners to move onto using more efficient strategies and hence potentially evolve their mathematical proficiency.

**Constructing a tool to enable visualisation of the data**

For continuity purposes, questions 9 and 10 will be used as examples. These 2 questions emphasise the procedural fluency strand and the LFIN component of strategies for counting and solving simple addition and subtraction tasks. The subsequent focus of this paper then is on ways of creating quantifiable and visual data from these 2 selected interview questions.

Having already spoken about the value of the data from this instrument for my clubs, I will now describe the process of constructing a tool to capture and summarise the data so that it is beneficial. The process described below details each stage of the process used to arrive at capturing the data from the learners’ scripts illustrating how the qualitative data is translated into quantitative data.

1. Working with the elaborated spectrums from Graven and Stott (2012), I entered each point of the spectrum into a spreadsheet as a header as shown below.
2. Following team discussion and guided by the definitions and examples provided by Kilpatrick et al’s Strands of Proficiency and the Wright et al LFIN levels, I noted which methods could be categorised as inefficient (I), efficient (E) or elsewhere in between (IE). These are added to the spreadsheet as shown in the bold boxes below.

3. I then moved on to creating calculations in the spreadsheet using Microsoft Excel IF statements to indicate where each learner is positioned along the spectrum for that particular question. A sample calculation is shown for question 10.

4. The main part of the spreadsheet was then ready to receive data from the scripts. From each script, I reviewed the notes made about methods used in order to decide which part of the spectrum that method falls into. I then entered a value of ‘1’ (in nominal form) under method used by the learner for that question (as shown above). Based on where you put the score, a ‘spectrum position’ indicator (I, IE or E) will appear using the IF
The final stage was to generate data that would provide the visual summaries I was looking for by way of graphs and summary tables. These next steps explain how I summarised the data. The visual examples shown below reflect the data generated from method questions only across the entire interview instrument.

5. SUMMARIES for LEARNER: For each learner, I created a matrix (or crosstab) to summarise the methods they used to answer method questions. I created counts of the number of different methods they used (using COUNTIF functions). I then worked out their predominant method by comparing the values in the matrix. A graph was then drawn from the matrix to give a visual picture of the data.

<table>
<thead>
<tr>
<th>Child Name</th>
<th>Efficient Methods</th>
<th>II Mixed Methods</th>
<th>Inefficient Methods</th>
<th>Predominant Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5</td>
<td>0</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>F</td>
</tr>
<tr>
<td>C</td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>R</td>
</tr>
</tbody>
</table>

Figure 8 - Summaries for Learner

6. SUMMARIES for CLUB: Similarly data was collated to give a club summary as follows. We can see in the example below, that 40% of the learners used constrained methods to answer question 9, whilst 50% of the learners used elaborated (flexible) methods to answer question 10.

Question 9:
- e.g. Add 10 to 92, add 10 to 294
- Take 10 from 50, take 10 from 700

Question 10:
- Incrementing 10s with dot strips

Figure 9 - Summaries for Learner

Conclusion

At the beginning of this article we conjectured if it was feasible to draw quantifiable, visual data from an orally administered instrument that qualitatively records learner methods of solution from observation. We have indicated why we believe this to be valuable and have
explained how a tool was constructed by the first author to translate qualitative oral interview data into visual, quantifiable data in the form of summary tables and graphs.

Such visual data enables one to gain different perspectives on the data at different points in time as well as to draw on the underlying stories that can be told from the qualitative perspective. We believe that this merging of visual, quantifiable data with qualitative data will assist in presenting a richer, deeper analysis of this data and that the quantifiable and qualitative will reinforce each other.

We hope that by presenting this we have indicated methodologically how qualitative data captured in a numeracy interview might be usefully translated into visually quantifiable summaries of learners’ proficiency levels at different points in time. We propose that this approach may be of value to other researchers working with the Wright et al (Wright, Martland, Stafford, et al., 2006) Learning Framework in Number or other such assessments or recovery instruments.

Acknowledgement
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References


Teachers’ perceptions of factors that contribute towards their effective practice: what the data tell us

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Abstract
This paper presents findings from a broader PhD study that aimed to explore and analyse the Geometry teaching practices of five purposefully selected secondary school teachers in Namibia who are regarded as effective mathematics teachers by their peers. The primary object of the broader study was to understand teachers’ perceptions of factors that contributed towards their effective teaching of geometry. This paper does not focus on effective teaching per se but on teachers’ perceptions of the factors that contributed to their success as effective mathematics teachers. The selected case study schools where the teachers taught were representative of high performing Namibian schools in terms of learners’ mathematics performance in the annual national examinations. This investigation was done through a process of classroom observations where the teachers’ instructional practices were observed and analysed using an adapted model of teaching for mathematical proficiency as developed by Kilpatrick, Swafford and Findell (2001) (referred to as Kilpatrick model). The study also used open-ended and semi-structured interviews with teachers. These interviews took the form of post lesson reflective and stimulated recall analysis sessions with the participating teachers. Teachers were asked to identify multifaceted factors aligned with some of the strands of the Kilpatrick et al. (2001) analytical tool that they believed influenced their own effectiveness in teaching mathematics. Part of the analysis of the data, from interviews with the five selected teachers, is presented in this paper.

1. Introduction
The notion of effective mathematics teaching central to this paper is multifaceted and shaped by many factors. These factors include a deep understanding of mathematical concepts and skills/repositories to creating an ideal environment that encourages positive learning outcomes for students regardless of their background and ability (Clarke and Clarke, 2004). Effective teachers have the ability to develop a variety of teaching strategies and practices to support students’ learning through careful planning, implementing and evaluating their lessons and also include a positive philosophy on pedagogy (ibid). Other factors that contribute to being an effective and successful teacher entail having a rich and wide content knowledge and a sound repertoire of conceptual teaching approach. That is, an effective teacher will have the means to successfully orchestrate effective classroom instructional practices. Further, an effective teacher will have an ongoing commitment to professional development and an ability to constantly interact with learners in the mathematics classroom. Despite the bad reputation that mathematics teachers have in Namibia (Stephanus and Schafer, 2011), there are beacons of excellence or scattered pockets of effective mathematics teaching. This study aims to take a closer look at these beacons of excellence. So, central to this investigation is the question: What are the instructional practices of effective Namibian mathematics teachers, and what are their views on their teaching of mathematics? In order to provide a content focus and, as geometry is a key area in the secondary school curriculum in which practical, real-life examples and contexts are very important, we specifically focused on this area of mathematics. This is because both teachers and learners experience geometry in everyday life. Therefore, they have everyday knowledge about geometry apart from mathematical knowledge or other mathematical domains. This paper presents part of the data
obtained from initial interviews with five effective mathematics teachers selected from five schools in different Namibian regions.

2. Purpose and context of the study
For the purpose of this study, effective teachers are those whose learners have consistently performed well in the national mathematics examinations. Further, they are teachers who have a high standing and good reputation in the mathematics education community, including the Ministry of Education. Askew, Brown, Rhodes, William and Johnson (1997) defined effective numeracy teachers as “highly performing mathematics teachers who have knowledge and awareness of interrelations between areas of the mathematics curriculum that they teach, and their classes of pupils had, during the year, achieved a high average gain in numeracy in comparison with other classes from the same year group” (p. 2). The latter is consistent with the selection of effective teachers in this study.

In order to analyse teachers’ perceptions of factors that contributed to their effectiveness as mathematics teachers, we needed to choose a framework to help conceptualise the various dimensions of effective teacher practice of teaching mathematics. We chose the Kilpatrick et al. (2001) model of mathematical teaching proficiency as a conceptual framework and analytical tool. We found the Kilpatrick teaching proficiency model useful to analyse effective teachers’ teaching proficiency because it was formulated on the notion of teaching for mathematical proficiency—a theoretical concept that is easily operationalized. The Kilpatrick (2001) framework builds on Shulman’s (1987) dimensions of general pedagogical models of teaching competence. The broader study also drew on elements of an enactivist worldview as a theoretical vantage point. For the purpose of this paper, however, the enactivist dimensions will not be discussed as we wish to focus on Kilpatrick’s et al. (2001) strands of mathematical teaching proficiency as a framework for analysing teachers’ practice. The conceptual and theoretical framework underpinning this study is described below along with its connection to the mathematics education literature and our study purpose.

3. Conceptual and theoretical framework
The work of Shulman (1987) proposed an in-depth look at what teachers must know in order to teach effectively. He highlighted that mathematics teachers need to be proficient in mathematics to be able to transform mathematically that subject matter content through teaching strategies to make that knowledge accessible to learners. To teach effectively, he argues, teachers need to have developed an integrated knowledge structure that incorporates knowledge about subject matter, learners, pedagogy, curriculum and schools. Such teachers should also have developed pedagogical content knowledge for teaching the subject content effectively. While Shulman (1987) identified general frameworks and models of mathematical knowledge for teaching (pedagogical content knowledge), Kilpatrick et al. (2001) introduced a comprehensive model of teaching for mathematical proficiency, which contains essential features for effective teaching of mathematics. Kilpatrick’s framework consists of five broad, interwoven strands of teaching proficiency. We adapted the five pedagogical dimensions of the Kilpatrick model to suit the teaching contexts of the participating teachers. In this study, the five strands provided a framework for exploring and analysing what constituted effective teaching in terms of teachers’ teaching knowledge, skills and abilities. Further, Kilpatrick’s model of teaching proficiency provided a useful framework for data analysis within a broader theory of enactivism. Enactivist perspectives suggest a move, or shift, from individual constructivist assumptions such as learner-centred education to a more practice-meaning-making approach modelled along complexity theory.
(Proulx, 2009; Stephanus and Schafer, 2011). As a useful extension of constructivism, enactivism was used to complement the Kilpatrick teaching model to conduct our analysis of effective teaching practices. Thus, the theoretical framework underpinning the study is that mathematical proficiency for teaching is embedded in the practice of teaching (Stephanus and Schafer, 2011). The manner in which our research project explored effective teachers’ teaching practices, along each of the dimensions of the Kilpatrick model, is described below.

3.1. Conceptual understanding
The first pedagogical dimension of Kilpatrick’s model is conceptual understanding of the core knowledge required in the practice of teaching (Kilpatrick et al., 2001: 380). Conceptual understanding refers to comprehension of mathematical concepts, operations and relations as required in the practice of teaching. In light of Shulman’s (1987) categorisation of mathematical knowledge, the core knowledge needed for teaching consists of mathematics content knowledge, knowledge of the development of learners’ mathematical thinking and knowledge of effective pedagogical practices. In Kilpatrick terms, this refers to teaching that encourages mathematical understanding or knowledge that is rich in mathematical relationships. In describing conceptual teaching, Xolo (2012) refers to underlying structures of mathematics, or in other words, the interconnection of the ideas that explain and give meaning to mathematical procedures. Within the arena of mathematical teaching proficiency, this means that a teacher should expose learners to mathematical understanding through investigation, exploration, discussions and sharing of ideas (Kilpatrick et al., 2001).

3.2. Procedural fluency
Kilpatrick et al. (2001) named their second strand procedural fluency, which refers to teaching that encourages knowledge or skills of rules, algorithms, or procedures used to solve mathematical problems or tasks. This competence is further described as teachers’ mathematical fluency in carrying out basic instructional routines (p. 380), which entails effective classroom management procedures and approaches to personal interactions with students. Stated differently, it refers to the teacher’s ability or skills to perform (carry out) procedures flexibly, accurately, efficiently and appropriately in different ways and contexts. Procedural teaching also refers to having factual knowledge and concepts that come to mind readily. Such teaching proficiency is vital to effective or successful mathematics teaching, since procedural fluency also refers to knowledge of procedures, symbols, rules, heuristics and formulas as well as knowledge used in solving mathematical problems.

3.3. Strategic competence
The third strand of Kilpatrick’s model is strategic competence in planning effective instruction (Kilpatrick et al., 2001: 380). A teacher with strategic competence can effectively engage in the problem solving activities, construct effective lessons plans, carry them out and interact meaningfully with learners in the mathematics classroom. Hence, Kilpatrick and his colleagues describe this teaching competence as the degree to which the teacher can appropriately integrate the use of instructional techniques with the mathematical concepts being taught and how effective these are for learners as part of the learner learning. Groth and Bergner (2005) note that strategic competence can play a role in shaping teachers’ instructional plans by showing that some pedagogical practices tend to be more effective than others. In other words, this teaching strand encompasses the ability to plan effective instructional activities as well as solve problems that arise during instructions (Kilpatrick et al., 2001). Sullivan (2011: 7) argues that this competence involves “devising strategies”,

69
which, he argues, includes a set of critical control processes that guide an individual to effectively recognise, formulate and solve problems.

3.4. Adaptive reasoning
The fourth teaching competence is adaptive reasoning. Kilpatrick et al. (2001) define adaptive reasoning as teaching that encourages or emphasises the capacity for logical thought, reflection, explanation and justification. This competence involves “mathematical reasoning in justifying and explaining one’s instructional practices and in reflecting on those practices so as to continuously improve them” (Kilpatrick et al., 2001: 380). This teaching strand or competence demands teachers, as critical reflective practitioners, to effectively plan and present particular mathematical problems to their students. Thus, a reflective teacher should incorporate mathematical thinking and reasoning that students manifest in learning processes.

3.5. Productive disposition
The last strand is termed productive disposition toward mathematics, teaching, learning and the improvement of one’s practice (Kilpatrick et al., 2001: 380). This component refers to teaching that encourages or instils a habitual inclination to see mathematics as sensible, useful, worthwhile, and coupled with a belief in diligence and one’s own efficacy (Kilpatrick et al., 2001). It refers to being able to see sense in mathematics and perceive it as worthwhile. Effective mathematics teachers should thus possess a positive disposition towards the subject and their teaching of the subject.

4. Research methodology and data source
This study is oriented within the qualitative framework, and is anchored within an interpretive paradigm. An interpretive case study research design was employed, involving five selected Namibian mathematics teachers, in order to investigate and deconstruct teachers’ geometric instructional practices “within its real-life context” of their mathematics classrooms and to gain “intensive, holistic description and analysis” (Yin 2003: 13). The Ministry of Education’s (MoE) archived statistical records of learners’ performance in the Junior Secondary Certificate (JSC) and Namibia Senior Secondary Certificate (NSSC) mathematics examinations in the last three years were used to select five teachers in order to analyse their classroom instructional practices.

Sampling was carried out in two stages. In the first stage of the broader study, a purposive sampling (Creswell, 2007) was used to select 10 Namibian secondary school mathematics teachers, who had consistently achieved the top results in the Grade 10 and 12 national examinations for the last three years (2008-2010). The second stage which is the focus of this paper, involved contacting these 10 teachers and inviting five volunteers to participate in our study. In order to secure the participation of the five teachers, we also selected them on the basis of (1) their voluntary participation and willingness to share teaching practice and experiences and (2) their qualifications. They needed to be qualified secondary school (Grade 10 -12) mathematics teachers with a minimum Basic Teacher Education Diploma (BETD) teaching qualification. Indeed, qualification was another criterion for selecting the teacher so as to ensure a reasonable foundation of mathematical knowledge and exposure to epistemological concepts associated with the pedagogy.

Semi-structured interviews and a stimulated recall participative analysis session were employed to generate qualitative data. “Semi-structured” means here that the interviews were
planned in advance but were dependent upon the interviewees’ responses, allowing for unplanned follow-up and clarifying questions. Teachers were interviewed about issues that emerged during the classroom observations. Importantly, teachers were challenged to reflect upon their own teaching practice. All interviews were tape recorded, transcribed verbatim and analysed within the Kilpatrick et al. (2001) framework. In analysing the interview data against the developed classroom observation checklist, we were interested in noting and documenting teachers’ own views about their effectiveness in their teaching of geometry as well as their interactions with learners. Emerging themes from the interview transcriptions were used to highlight teachers’ teaching practice features and utterances and their perspectives of practices they considered important for effective teaching. The specific components of the study design are outlined in detail in the next sections.

4.1. Participants
Five mathematics teachers (two males and three females) participated in this study. Even though gender was not a central factor in this research, it is important to point out that the dominance of female mathematics teachers in our sample of participating teachers was neither purposive nor deliberate, and may not be representative of mathematics teachers in Namibia. Table 1 below summarises information about the participating teachers. In this study, the participants and schools have been categorised and coded as follows. Teacher 1 is referred to as Demis of school A, teacher 2 as Jisa of school B, teacher 3 as Ndara of school C, teacher 4 as Emmis of school D and teacher 5 as Sann of school E. These are the pseudonyms assigned to the five mathematics teachers and their respective schools. Our five case study schools are spread across five regions in Namibia, namely, Omusati, Oshikoto, Otjozondjupa, Khomas and Erongo.

Table 1 Summary of case study participants and schools

<table>
<thead>
<tr>
<th>School</th>
<th>School type</th>
<th>Teacher and Name</th>
<th>Sex</th>
<th>Age</th>
<th>Levels of study</th>
<th>Teaching experience in years</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Public</td>
<td>T1: Demis</td>
<td>Female</td>
<td>&gt; 40</td>
<td>Gr.12, B.Sc, HED</td>
<td>20</td>
</tr>
<tr>
<td>B</td>
<td>Private</td>
<td>T2: Jisa</td>
<td>Female</td>
<td>30-40</td>
<td>Gr.12, B.Sc, M.Sc, B.Ed</td>
<td>10</td>
</tr>
<tr>
<td>C</td>
<td>Public</td>
<td>T3: Ndara</td>
<td>Male</td>
<td>30-40</td>
<td>Gr. 12, B. Science</td>
<td>6</td>
</tr>
<tr>
<td>D</td>
<td>Private/Day</td>
<td>T4: Emmis</td>
<td>Male</td>
<td>&gt; 40</td>
<td>Gr. 12, B.Ed, M.Ed</td>
<td>15</td>
</tr>
<tr>
<td>E</td>
<td>Private/Day</td>
<td>T5: Sann</td>
<td>Female</td>
<td>30-40</td>
<td>Gr. 12, HED</td>
<td>8</td>
</tr>
</tbody>
</table>

4.2. Data analysis
The data analysis was inseparable from the data collection. Data was analysed using descriptive narratives (Cohen, Manion and Morrison, 2007). This was done in order to render a description of teachers’ classroom instructional practice in relation to their teaching proficiency based on teacher content knowledge questionnaires, classroom lesson observations and interview data. Data from all data sources were transcribed verbatim, and thereafter were coded based on the aforementioned concepts of an adapted Kilpatrick’s model of teaching proficiency (Kilpatrick et al., 2001). Each of the data sources were colour coded to look for similarities and differences as well as odd occurrences. Codes based on the Kilpatrick pedagogical concepts were assigned to segments of teachers’ responses during interviews. Such responses reflected enabling factors that teachers perceived as influencing their teaching effectiveness. After codes had been assigned, a clustering procedure (Creswell, 2007) was used to gather data into categories. Excerpts that show some evidence of teachers’
perspectives are used to elucidate teachers’ understanding of their own effectiveness. The results section represents the negotiated consensus of both authors with regard to how the interview data were coded and categorised.

4.3. Results
4.3.1. Some exemplary teaching and learning experiences from Namibia
As we analyse and present teachers’ perspectives of their own effectiveness, we use selected excerpts from interview data that related to our focus in this paper. The analysis of teachers’ responses from interviews identified broad themes of key factors or characteristics of effective teaching. These themes were further categorised into a mix of external and internal factors that are important to consider in relation to teacher effectiveness. The external factors, in this study, refer to factors enabling effective teaching that are outside the teachers’ control. They represent opportunities presented by the external environment. These include school management and leadership and efficient organisation, teacher collegiality, collaboration and teamwork, and effective links with the broader community. The internal factors refer to key factors enabling effective teaching within teachers’ control. These include teachers’ educational background and experience; commitment, hard work, discipline and passion for mathematics. In addition, a conceptual approach to teaching, structured and well-planned lessons and high expectations (of themselves as teachers and of the children in terms of high cognitive tasks) were also identified as internal factors to consider. Additional internal factors include the ability to adapt curriculum to suit needs, use of high level content, purposeful assessment of learning, a supportive and conducive learning environment; and the use of graded homework assignments to enhance understanding of mathematical concepts. Not all these factors will be discussed in this paper due to space constraints. We will only discuss the following themes: influence of effective school management, leadership and efficient organisation, influence of teacher collegiality, collaboration and teamwork, effectiveness of the links with the broader community, conceptual understanding of core knowledge, conceptual approach to teaching, school policy on homework, structured and well-planned lessons, influence of commitment, hard work, discipline and passion for mathematics. As we wish to let the narratives of the participants come through and be heard, we let the “conversations speak for themselves and hence reproduce detailed extracts of the transcripts” (Schafer, 2003: 183), except where otherwise noted.

4.3.2. External factors
4.3.2.1. Influence of effective school management, leadership and efficient organisation
Almost every teacher indicated effective school management or leadership to be a key potential factor in enabling them to be more effective. Teachers are of the opinion that effective management is more committed to instructional leadership, effective teaching and the development of the school. Similarly, teachers appear to reveal that effective teaching or good performance and efficient organisation goes hand in hand with effective school management. They indicated that quality instructional and assurance measures implemented from school management encouraged effective teaching practices amongst staff. In addition, effective school management ensures that both quality teaching and assurance measures are supported in their schools, and that the performance standards are set and maintained.

Effective management or leadership in this context means “being clear about what needs to be done in terms of school aims and policies, taking steps to ensure that the work is done well, taking steps to evaluate whether things are working as well as using the evaluation to make the necessary changes” (Namibia-MoE, 2005a: 2). Teachers implicitly underscored the role that principals play and identified their management style, their efficient organisation,
and their relationship to the vision, values and goals of the school and their approaches to change as significantly imperative for effective teaching, as manifested in the excerpt below.

> So, management is number one. Like here at [this school], I think the management is very good...seriously people...people who are dedicated to their work. It is like their lives depend on this job. And that makes the whole system now very effective...very, very effective (Teacher 4: School D). Yah, personally if I tell you the truth, I do enjoy my teaching because there is enough support from the management (Teacher 4: School D).

4.3.2.2. Influence of teacher collegiality, collaboration and teamwork

Mathematics teachers further emphasised the importance of networking with other professionals. Teachers indicated that collaboration with other teachers within and outside the school directly support and assist their instructional strategies and selection of teaching materials. This teacher collaboration platform typically involves two or more teachers working together to determine what learners need to know and what or how they should be taught. The participating teachers explained that they routinely work in partnership to plan with one or more teachers at the school, who are usually teachers of the same grade level, in order to provide a consistent program for their learners. A number of the participating mathematics teachers characterised such collaborative meetings as formal planning sessions whereas others portray these meetings as informal idea exchanges. In both cases, teacher collegiality, collaboration and teamwork enable a strong interactive culture of sharing of teaching strategies and materials for use in lessons. The quotations below illustrate the above.

> The other thing we do here is that we have to share ideas with other colleagues within the school (Teacher 2: School B).

> We had a group of teachers from Omaruru. They come (sic) and visited us for a week. They were in our classrooms. We were giving them worksheets, questions (sic) papers and everything that we were giving to the kids. They could observe how we are teaching and I think that this is a good idea to go around and actually observe other teachers of how (sic) they are teaching and what they are doing...because if I do not know how to teach certain concepts, I won’t find it in the textbook. In the textbook I find guidelines, but I have to see how it is being done before I will be able to do it properly (Teacher 5: School E).

4.3.2.3. Effectiveness of the links with the broader community

The data showed that effective schools are underpinned by a broader principle of working with the community. The study results show that effective schools work well with the wider community for the purposes of ensuring that the relevance of teaching and learning and the safety of students in the schools are not compromised. In this context, a shared and committed school leadership requires commitment from all education partners or stakeholders. Hence, the links with the broader community is a foundation of excellence and effectiveness. Essentially, the links with parents and other well-performing schools sustain effective teaching. These links also enable school managers to conduct school self-evaluation, secure other school- or community-based support, involve parents in school activities and co-ordinate effective teaching practices. It is also vital for collaborating with all education stakeholders involved and drawing upon a wider community to enhance effective teaching and learning, including analyses of aspects of effective school practices. We are thus
arguing that school effectiveness networking helps to create a community of practice and improve classroom practices. It also provides schools with a set of tools to develop effective teachers. This set of tools and, thus, teacher effectiveness systems help teachers to network with other teachers through professional development activities, put into practice effective ideas/practices they gained, reflect on their practice with colleagues and to get 100% pass rates in national examinations.

4.3.3. Enabling internal factors for teachers to be effective

4.3.3.1. Conceptual understanding of core knowledge
In the interview, teachers indicated that their educational backgrounds and experiences are useful in developing understanding of the knowledge base needed for effective teaching. In most cases, teachers reported that their pre-service and in-service training may have contributed to their knowledge of, and confidence with, various pedagogical practices. Teachers also emphasised teaching important core concepts so that their learners develop authentic understanding of those concepts. Teachers said, for example:

As far as the subject content is concerned I think I am well equipped. The training that I went through has prepared me enough for me to handle the concepts at this grade level (Teacher 3: School C).

I was trained and I think I was trained effectively. I was trained how to plan...I was trained how to develop concepts...how to introduce concepts and how to create a contradiction in the [mind of] learners...create the thinking mind in the learner (Teacher 4: School D).

Well, I think the fact that I had proper mathematics teachers also made a big difference (Teacher 5: School E).

4.3.3.2. Conceptual approach to teaching
Analysis of interview data suggested that all participating teachers have the necessary knowledge for conceptual teaching as determined by the education ministry officials. We have identified three conceptual approaches to teaching strategies that participating teachers employed to promote learners’ conceptual understanding. The first approach entails techniques that make mathematical concepts more live and engage learners to see connections between mathematics and the real world. The second teaching strategy suggested by teachers builds on learners’ existing ideas and extends them to new concepts. All teachers involved learners in doing mathematics through practical work. Teachers liked giving their learners a lot of practice to make learners become aware of the concepts in their thinking. Teachers implied that Practice makes perfect and is necessary to master any skill. Teaching for conceptual understanding is typical of effective teaching (Kilpatrick et al., 2001). In Kilpatrick’s terms, this can be described as conceptual understanding in that, if teachers give more examples or practice for learners to do, they will acquire the rules as well as the meaning that underlie those mathematical concepts.

A third approach to effective teaching that teachers mentioned refers to creating a democratic classroom environment within which students are seen as active co-participants and member of collaborative groups, and where they feel confident and able to express and discuss their views openly. Such an environment can only be created through the teacher being simultaneously sensitive to learners’ needs, feelings and ideas as well as an effective manager
of a class group. Teachers had also pointed to the need to, mostly, giving learners explanations aimed at deepening their conceptual understanding and making connections between different concepts. Said these teachers:

We also give learners extra practice and extra time of mathematics lessons and this makes our learners to understand concepts easily (Teacher 2: School B).

4.3.3.3. Strategic competence
The second broad area participants identified as central to their effectiveness was their strategic competence in planning and presenting particular mathematical problems to their students. Also, they said that their personal teaching experiences, their mathematical backgrounds and experiences as mathematics learners contributed to the way they taught. All teachers also noted that the type of mathematics teachers they had, either during their secondary school or their tertiary education, has contributed to their knowledge of how learners learn best as well as how they should be taught. Likewise, all the teachers described a number of significant pedagogical strategies that they were exposed to during their pre- or in-service training periods that have shaped their current practices. These pedagogical strategies include: rich questioning to deepen learners’ conceptual understanding, interlinking concepts, use of hands-on or multiple teaching approaches (investigations, practical, discoveries) to engage learners with the mathematical concepts, and interacting with their learners while involving them in doing their own practical learning. Some of the evidence for this is found in the following excerpts:

I like practical lessons...my yesterday lesson (sic) was on circle theorem...I involve them in practical (sic) to derive the theory, to discover the theorems so that they can use them in future and in any other development (Teacher 4: School D).

Explain the general rules. So the whole time when you teach, you have to take the students back to the general rule...go to more basics (Teacher 1: School A).

I use (sic) to relate it to the real-life situations of the learners...contextualisation in real-life situation is the best (Teacher 3: School C).

4.3.3.4. School policy on homework
All participating teachers emphasised the importance of homework. At all the participating schools, homework is compulsory. From the perspectives of the teachers collectively, it was found that homework is a daily activity and given for a number of reasons. Firstly, homework is given to cultivate a sense of learner responsibility towards learning. Secondly, teachers assign homework for learners to do more practice. For all the teachers, it was important that homework enabled them to see what learners can do or not do and to enable their learners to hone their skills and comprehend mathematical concepts they are taught. Teachers also viewed the homework as an extension of the executed lesson during which learners are engaged in individual practice or seatwork. According to these teachers, it could be inferred that the homework plays a significant role in teaching mathematics effectively. For example:

But yah...homework in our school is a daily thing (Teacher 4: School D).

4.3.3.5. Structured and well-planned lessons
The interview data highlighted the importance of structured and well-planned lessons. The participating teachers took it upon themselves to make their lessons interesting and to motivate learners to feel excited about learning and to make connections to mathematical concepts under discussion. The data showed that the participating teachers planned well and presented the lesson contents or materials in a well-organised format. Most teachers felt that well-planned lessons influence learners to take responsibility for their own learning, and this is certainly a legitimate position. For instance, teachers reported using carefully planned introductory questions, correcting homework and then posing some old examples to check learner facility with prerequisite skills. They also presented some new examples, asked students to complete some illustrative tasks and posed further questions in sets of similar complexity. Some teachers provided clear demonstrations or definitions of concepts, demonstrated the link between concepts and assessment strategies, posed a problem to start a discussion, occasionally asked learners to justify and explain their mathematical ideas, thinking or methods to solution and/or situated mathematics within a realistic context to engage students with concepts. In addition, teachers indicated posing some further examples to the class to check both the students’ accuracy and their capacity to explain the process they use, before they set further examples for homework. One of the teachers said:

*Part of it is the “Structure”...the way that we structure or sequence our work or concepts in a clear and proper sequential or hierarchical order. I am not just going to do this and that, but the ORDER of concepts is most important. For me the structure helps a lot towards effectiveness...there must be a coherent structure among concepts to be taught (Teacher 1: School A).*

4.3.3.6. Adaptive reasoning
Adaptive reasoning was also evident from teachers’ responses. Teachers asked open-ended questions to build learners’ understanding of concepts while focusing learners’ attention on key elements of the learning content. For example, teachers reported encouraging mathematical reasoning in their teaching by asking “why” questions that solicit learners to explain and justify their answers and ideas. “Why” questions about facts or procedures that students engage with are rather frequent, being asked, mostly, in order to give mathematical meaning to ideas or procedures, meaning of steps or solution methods and, explain or clarify responses of the learners. According to Kilpatrick and his colleagues, such teaching foregrounds adaptive reasoning, which is the capacity for logical thought, reflection, explanation and justification. This competence involves justifying and explaining one’s instructional practices and in reflecting on those practices so as to continuously improve them (Kilpatrick et al., 2001). Similarly, teachers indicated bringing in investigations to enhance learners’ mathematical reasoning. For example:

*Another similarity is that we all encourage reasoning by asking questions like “why”, “tell me why”, “how did you get that”, “why a procedure works”, “why a solution method makes sense” or “why the answer is correct” to see if they really understand or grasped taught concepts (Teacher 1: School A).*

4.3.3.7. Productive disposition
4.3.3.7.1. Influence of commitment, hard work, discipline and passion for mathematics on teacher effectiveness: It is interesting to note that commitment and hard work amongst the teachers and the learners, and the passion for mathematics have a far-reaching influence on teachers’ effectiveness and learners’ performance in the mathematics classroom. On many
occasions, teachers indicated that they are committed, hardworking and consistently enforce fair, clear and well-understood rules to maintain discipline among their learners. They also indicated having a high passion for mathematics teaching. This trait was evident from the way teachers were articulating themselves during the interviews. The following extracts are typical of teachers’ commitment, hard work and disposition.

*I am sure this goes with a commitment of the teacher. Actually when a person is appointed to the job, the first thing you are commanded is to work hard and deliver on the mandate entrusted with you...you should motivate your learners, you should make your learners do the work, and you should also make sure that they [learners] in as much as they can understand the concepts. I think these are the basics of which a person may [well] achieve the target* (Teacher 3: School C).

*I think the first thing is just the general part of personality that I have a passion for mathematics. So, for me it is very important that you must love mathematics and that you must transfer that love for mathematics over to your students* (Teacher 1: School A).

**Concluding remarks**

At most, this study aimed to provide some interesting insights into the teaching practice of effective mathematics teachers, and to find out the kind of teaching proficiency these teachers draw on in teaching geometry and developing proficient students of mathematics. These results are tentative in that they are a fraction, or micro-analysis, of a larger set of data that are currently being analysed. Both external and internal factors presented here illustrate what teachers perceived as contributing towards their effective practice, and have implications for effective teaching. All five teachers shared similar understandings of their effectiveness in teaching mathematics in Namibia. The pedagogical conclusion of this study is that effective teaching practices in complex mathematics classroom settings have a strong influence on students’ learning and understanding of mathematical concepts.

**References**


Students’ conceptualizations of 3-variable functions and the role of visualization in the learning of multivariate calculus

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Abstract
This paper focuses on undergraduate students taking Calculus course in a BEd degree programme offered at local university in Zimbabwe. The paper analyses student conceptions and misconceptions on the graph of surfaces by use of visuals which were constructed using mathematical software called ‘Mathematica’. The theoretical frameworks used focussed on conceptual understanding. The results indicated that students conceptualise better through use of visuals and also the use technology which plays a key role in enhancing better understanding of calculus concepts motivated the researcher to investigate on this area.

Key words: Conceptions/misconceptions/errors in mathematics, graphs of surfaces, multivariate calculus, graphical representations.

Introduction
Students have interacted with drawing graphs of functions as early as primary level. Graphs sometimes are very easy to conceptualise the characteristics of a model in problem solving than explanations. Practices in mathematics problem solving are often based on verbal representations that make use of logical connectives in sequential reasoning. According to Diezmann, (1997) recent research in mathematics teaching however has advocated the use diagrammatic explanation to assist comprehension. Tall (1991) claimed that the ways of representing a mathematical situation are: symbolic, graphical, numerical and verbal. It is important to be able to use each of them, and to translate from one form to another. During my career as a mathematics teacher and lecturer at several schools, colleges and universities I discovered that analytic thinking is characteristic of a few groups of students while the majority benefit from visual thinking. This argument is supported by Whiteley (2004) who asserts that visually based pedagogy opens mathematics to students who are otherwise excluded.

In this study the researcher explores students’ conceptions and misconceptions on the graphs of surfaces by undergraduate students taking the course of Calculus of several variables. The objective of the research is to reinforce students ‘conceptions of graphs on single variable Calculus, transferring such concepts to the graphs of surfaces. For example in single variable Calculus students were able to draw the sketch of y=sinx, being able evaluate its domain and range. Are students going to use the same analytic methods for the graph of z=sinxy? What properties are preserved by such functions in space geometry? However the main question is: what conceptions and misconceptions of the graphs of surfaces do students develop in a course which emphasises visualization, uses of technology, and deemphasises symbolic manipulation?

Errors and misconceptions
According to Hammer (1996) a misconception happens when a person believes in a concept that is objectively false and generally misconceptions manifest through errors. Misconceptions are then strongly held stable cognitive structures which differ from expert
conceptions and affect in a fundamental sense how students understand natural scientific explanations and must be avoided.

Theoretical framework
Stewart J. (1999) asserted that the primary aim of Calculus instruction is the emphasis on understanding concepts. In fact the impetus for the current Calculus reform movement came from the Tulane Conference in 1986, which formulated as their first recommendation: focus on conceptual understanding. He also went on to emphasise that the most important way to foster conceptual understanding is through the problems we assign. In this study the researcher also used the Cognitive Dissonance theory by Festinger, (1957) and Cognitive Flexibility theory by Spiro et al, (1990). Dissonance theory applies to all situations involving attitude formation and change. Wickland et al (1976) argue that this theory is especially relevant to decision-making and problem-solving. When there is an inconsistency between attitudes (dissonance) something must change to eliminate the dissonance. This theory shall be useful to students when constructing graphs of functions in space. Some properties of functions of single variable are going to be inconsistent with functions of several variables, for example, the criteria for evaluating critical points. Flexibility theory is especially formulated to support the use of interactive technology. Spiro et al (1990) asserts that the main principle is that learning activities must provide multiple representations of content. This will be applied when Computer Algebra Systems (Mathematica) is going to be used to draw graphs and level curves of functions of several variables. Students should then associate functions with their graphs and level curves creating a chain of symbolic representation, plane representation and space representation.

Visualization
Is a picture worth a thousand words? It seems so, as historical accounts of scientific discovery and invention have shown that visualisation is a powerful cognitive tool as claimed by Rieber, (1995). The term visualisation is familiar to us from common usage and fundamentally means “to form and manipulate a mental image”. In everyday life visualisation is essential to problem solving and spatial reasoning as it enables people to use concrete means to grapple with abstract images. The process of visualisation involves the formation of images, with paper and pencil or even mentally, to investigate, discover and understand concepts, facts and ideas. Pictorial and visual forms of representation can offer advantages over text-based resources by offering scope for: displaying spatial interrelationships and facilitating perceptual inference (e.g. relative size of objects).

Visualisation has been accounted for by a number of theorists who have indicated its centrality in reasoning and learning. Bruner (1984, p. 99) characterises two alternative approaches to solving problems, one being intuitive, and the other analytic. McLoughlin & Krakowski (2001) argue that visual representation of ideas is just as much a part of the learning process as using language and other symbolic representations, yet current theories of learning with technology do not always highlight this important dimension of the learning process. Theorists have emphasised that visual thinking is a fundamental and unique part of our perceptual processes and that visualisation is a partner to the verbal and symbolic ways we have of expressing ideas and thoughts.

Graphs of surfaces
It is very difficult to visualise a function f of three variables by its graph, since that would lie in a four-dimensional space. However we do gain some insight into f by examining its level
surfaces, which are the surfaces with equations \( f(x,y,z)=k \), where \( k \) is a constant. For example find the level surfaces of the function \( f(x,y,z) = x^2 + y^2 + z^2 \).

Solution: The level surfaces are \( x^2 + y^2 + z^2 = k \), where \( k \) is positive. These form a family of concentric spheres with radius square root of \( k \) and centre \((0,0,0)\).

![Graph of the function \( x^2 + y^2 + z^2 = 4 \) (\( k=4 \)).](image1)

The above graph can further be represented by level curves on a plane, for instance \( f(x,y) = c \) where \( c \) is a constant. In this case \( z=f(x,y) \) and \( z=c \) will result in \( x^2 + y^2 = 4-c \) for \( c < 4 \).

![Level curves for the function \( f(x,y)=x^2+y^2 \)](image2)

**Technology**

The availability of technology makes it more important to clearly understand the concepts that underlie the images on the screen. When properly used graphing calculators and computers are powerful tools for discovering and understanding those concepts. The two diagrams above were drawn using Mathematica Version 4.0. Technology does not make pencil and paper obsolete. Hand calculations and sketches are often preferable to technology for illustration and reinforcing some concepts. Both instructors and students need to develop the ability to decide where the hand or the machine is appropriate. Thomas, D (1995) argues that contemporary graphing technologies in the hands of students will enhance their learning. Almost all Computer Algebra Systems are capable of drawing graphs in two and three dimensions that is why they are excellent visualisation tools. The software tools and the computer screen can serve as a **scaffold** or support for dialogue, reflection and learning, becoming in effect cognitive tools for learning.
Methodology
Design of study
In this study the major objective was to identify students’ conceptions and misconceptions on the graphs of surfaces. The sample for this experiment was composed of 13 B.Ed. students specialising in mathematics at secondary level taken from the population of all B.Ed. students in the Department of Curriculum Studies. The participants were first years taking a course of Advanced Calculus. The course covers both single variable and multivariable calculus. The students were taught the concepts graphs of functions in single variable calculus and this concept was further developed to graphs of functions of several variables. The teaching process was done with the aid of Mathematica which is a special tool in the drawing of level curves and 3-D graphs. The design of the study was of the form Experiment–Observe (X-O). The research methodology is quantitative in nature.

Research instrument
The research instrument was a calculus exercise taken from the topic of Geometry of Space. The exercise consists of two questions. The objectives of question 1 were to describe various given functions of surfaces and also to sketch the graph of the respective surface. The objective of question 2 is to match function, graph and level curve respectively. (See table 1 below)

Validity and reliability
To test validity and reliability the research instrument was first tested on students who had completed Calculus I and Calculus II in the Faculty of Science. The paper was also scrutinized by experts at a local conference in July 2012 at Gweru Baptist Centre in Zimbabwe.

Table 1. Research instrument: Test on students’ conceptions and misconceptions of surfaces.
1. Answer all questions on spaces provided.

<table>
<thead>
<tr>
<th>Function/equation/inequality</th>
<th>Describe the region corresponding to the given equation/inequality in R^3</th>
<th>Sketch the graph of the region</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) X=9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) X=-8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) X^2+y^2+z^2=1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) 1&lt; X^2+y^2+z^2&lt;25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(e) X+y+z=1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Match the function with its graph and level curves.
(a) z=sinxy
(b) z=x+y
(c) z=x^2+y^2
(d) z=x^2+y
(e) z=x^2-y^2

<table>
<thead>
<tr>
<th>FUNCTION (a-e)</th>
<th>GRAPH (I-V)</th>
<th>LEVEL CURVE (A-E)</th>
</tr>
</thead>
<tbody>
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<td></td>
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</tbody>
</table>

82
Fig. 3. Graphs of functions in question 2

I.

II.

III.

IV.

V.

Fig. 4. Level curves of functions in question 2
Each task was graded on a four point scale with the following scale: Correct (3), Partially correct (2), Incorrect (1), Missing (0). The test consisted of three factor levels which were to be analysed. The first being descriptions of regions (question1), the second factor being
sketching of the graphs of regions (question 1) and the third factor was matching function - graph-level curve (question 2).

**Treatment**
The study was conducted in a course (Advanced Calculus) designed to learn the concepts of both Calculus 1 and Calculus 2 in one semester. Students were first taught single variable calculus (Calculus 1) and then multivariable calculus (Calculus 2). The research was then focused on the first concepts of multivariable calculus which is the geometry of surfaces. This section is very vital in multivariable calculus. For students to be able to perform multiple integration it is vital that students are able to describe and sketch the graphs and level curves of multivariable functions. The concepts on Question 1 were function and graphical representation in space using pencil and paper. The concepts on Question 2 were function, graphical representation in space and level curves on the x-y plane. The graphs of functions and level curves were provided to the students drawn using Mathematica 4. Students were not tasked to use computers to draw these graphs.

**Students’ procedures and conceptions**
The analysis of students’ written responses revealed significant information regarding the nature and characteristics of students’ conceptions on surfaces. The table below is a summary of results of the distribution of scores on the written exercise. [Correct (C)=3, Partially Correct (PC)=2 , Incorrect (I)=1, Missing (M)=0]. For convenience, in this research all Correct and Partially Correct answers shall be regarded as students’ conceptions and incorrect answers shall be classified as errors and / or misconceptions (depending on the nature of error).

**Table 2: Summary of results of the written exercise**

<table>
<thead>
<tr>
<th></th>
<th>1(a)</th>
<th>1(b)</th>
<th>1(c)</th>
<th>1(d)</th>
<th>1(e)</th>
<th>2(a)</th>
<th>2(b)</th>
<th>2(c)</th>
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### Table 3: Classification and distribution of errors for each task

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<tr>
<th>No.</th>
<th>Equation/Inequality</th>
<th>Errors/conceptions</th>
<th>Description</th>
</tr>
</thead>
</table>
| 1(a) | $x = 9$ | General conception: It is a plane which cuts the x-axis at $(9,0,0)$  
Misconception: It is a line on the plane. It is along the x-axis passing through $(9,0)$  
Misconception: It is a plane parallel to the point $X=9$. | Correct response: Plane parallel to the yz plane passing through point $(9,0,0)$  
Most students left out the concept of parallelism. Two students misconceive the plane for a point in the real line. One student misconceived a plane being parallel to a point. Students were able to draw the graph of the equation. |
| 1(b) | $z = 8$ | Same as above 1(a) | Same as above 1(a) |
| 1(c) | $x^2 + y^2 + z^2 = 1$ | Misconception: It is a circle of radius 1 unit. | Correct response: Sphere with centre $(0,0,0)$ and radius 1 unit.  
Two students mistook the equation of a circle on a plane with the equation of a sphere in space. A majority of students were not able to construct the graph of the relation. |
| 1(d) | $1 < x^2 + y^2 + z^2 < 25$ | Misconception: Two circles/discs  
General error: Students were not able to clearly construct the required region. | Correct response: Region between two spheres of radii 1 unit and 5 units respectively.  
Almost all students were not able to describe the inequality and were not able to construct the required region. |
| 1(e) | $x + y + z = 1$ | Misconception: It is a line with domain $+1$ and -1  
Misconception: It is a prism triangular in shape… | Correct response: Plane cutting all the axes at points $(1,0,0)$, $(0,1,0)$ and $(0,0,1)$.  
Two students mistook this plane for a straight line and one student mistook the plane for a triangular prism. Students were able to construct the graph of the equation. |
| 2(a) | $z = \sin xy$ | Not applicable | To answer this question student were... |
to exploit the characteristics of sinx. Two students mistook the level curves of equation for that of $z=x^2+y$

<p>| | | |</p>
<table>
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<td>$z=x^2+y^2$</td>
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<td>2(e)</td>
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**Conclusions and recommendations**

Taking consideration of the results from the given exercise, the researcher noted the following important observations which are answers to the main research question:

**Visualization**

Question 1 comprised of two sections. The first section was description of the equation, without emphasis on visualization. The second section was drawing the graph of the given equation. The results showed that about 85% of the students were more comfortable with drawing the graph rather than giving the description of the equation. Most students attempted section two first and then section one last by describing what they had constructed. It can be concluded that students conceptualise better through use of visuals.

Question 2 also comprised of two sections. However both sections were to be answered from the given visuals. Students were supposed to match the graph and its level curves. From the results the total for incorrect responses was 7, implying that 90% of the responses were either correct or partially correct. It can also be concluded that students performed much better on question 2 than on question 1.

**Use of technology**

From the results of the exercise most students struggled with constructing of graphs of functions in 3-dimensions. Question 1 could have been enhanced if students were tasked to use the computer to construct these graphs as evidenced by the graphs provided in question 2. Without use of technology clearly it could have been impossible to accomplish question 2. This approach of questioning borrowed from the textbook of Stewart J (1999, pp 917-921) is only possible through the assistance of Computer Algebra Systems.

The students responded positively to question 2, implying that the idea of using computers is very vital in calculus. The only drawback is that there is not enough time for both computers and calculus. It was observed that the use of computers had a dual purpose of facilitating and deepening the understanding of calculus concepts and also produced positive changes of students’ attitudes toward the subject.

**References**


Pedagogic strategies used by educators who do not speak the learners’ main/home language for proficient teaching of functions in multilingual mathematics classrooms.

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Abstract
Research has long acknowledged the role of pedagogic strategies such as code switching in the teaching and learning of mathematics in multilingual context. Some of these strategies, however, are more effectively employed if the teacher shares the same home language as most of the learners in the class. A good number of foreign teachers teach in multilingual classrooms in South Africa. At JBC (pseudonym) school, the matric results have steadily improved over the years despite the fact that the foreign teachers who teach mathematics at FET level do not share a common home language with the learners. This qualitative case study had for aim to establish the teaching strategies used by these foreign educators for proficient teaching of mathematics in multilingual classrooms and how they encourage learner participation in the teaching of functions. The study was informed by Kilpatrick, Swafford and Findell’s (2001) five components of proficient teaching of mathematics. Two foreign teachers teaching functions in two Grade 11 classes were observed and interviewed. The findings revealed that the two teachers have access to a range of teaching strategies which they employ fluently and appropriately. Linking previously learnt material to new concepts, exploration over a well thought out example space, sequencing and predicting mathematically were used to promote mathematical proficiency. To encourage learner participation in mathematical discourse, the teachers used adjusted speech, revoicing and group dynamics. It is recommended that teachers should have access to a range of strategies and be able to adapt them to suit their situations and mathematical content.

Introduction
In response to manpower demands in education due to critical shortage in the mathematics and science fields, South Africa opened its doors to foreign and qualified educators. As a result, in 2007 there was an influx of foreign mathematics and science educators. JBC School where I am teaching mathematics, benefited from the influx. However, some of the foreign educators teach multilingual classrooms where English is the language of instruction but not the learners’ first, main or home language. As it can be expected, in most cases, these foreign educators do not speak any of the home languages.

The crucial role of language in conceptualisation and reasoning in mathematics has been acknowledged a long time ago by researchers such as Vygotsky (1962) and Pimm (1987). In a more recent research, Setati (2008) claims that using the learners’ main language improves learner understanding and participation in mathematical discourse. The use of the learners’ main language in a multilingual classroom becomes a challenge if the teacher cannot speak any of the home languages. Yet, at JBC, the matric results in mathematics have gradually improved since the foreign teachers became employed in the school. The question of what these foreign educators are doing right to effect such a positive change arose. As a result, this study focused on the strategies employed by educators who do not speak any of the learners’ main language in an English medium multilingual classroom to promote learner participation...
in mathematical discourse and the development of mathematical proficiency. Hence, this study was guided by the following research questions:

- What pedagogic strategies do educators who do not speak any of the learners’ main/home language use for proficient teaching of mathematics in the teaching of functions in multilingual classrooms?
- How do these teachers encourage participation in the class?

My definition of proficient teaching of mathematics resonates with how it is defined by Kilpatrick, Swafford and Findell (2001). These authors defined proficient teaching of mathematics in terms of five interwoven and interrelated components which are: conceptual understanding of core knowledge, fluency in instructional routines, strategic competence in planning effective instruction and problem solving, adaptive reasoning and productive disposition towards one’s teaching practice.

Research in South Africa has shown that teaching and learning mathematics in multilingual classrooms is complex (Essien, 2010). In earlier studies, Adler (1995) noted that teaching and learning mathematics in multilingual classrooms involve dynamic interplay among proficiency in the language of instruction (English in the case of this study), access to mathematics register and social diversity and relations in the classrooms. In order to establish the strategies used by educators who do not speak any of the learners’ main/home language in teaching mathematics in multilingual classrooms I review the three sources of information mentioned above.

**Social diversity and classroom relations**

Due to the high economic activity in the province, Gauteng (the province where the school of study is located) becomes a racial, cultural and linguistic melting pot. The school community becomes widely multilingual. Research has shown that most parents and learners in South Africa prefer learning in English due to social, economic and political reasons (Setati, 2008) even though the South African constitution allows the use of any of the twelve official languages for instruction.

Where the language of instruction is different from the learners’ home/main language the teacher may have to teach the language, enforcing the language of instruction and teaching the mathematical content (Mercer, 2001). Achieving these three goals is not as clear cut. Adler (2001) viewed the teacher’s role in a multilingual classroom as faced with dilemmas which are:

- Code-switching, this may favour one language which may not be a main language for all the learners.
- Mediation as the teacher moves towards the learners’ preferred language.
- Transparency in the case of choosing between implicit and explicit teaching of mathematics language.

While it might be a series of dilemmas for a teacher who can speak some of the learners’ first languages it is impossible for a teacher who does not speak any of the learners’ home/main languages to support the learners as mentioned above.

**Teaching and learning mathematics in English as a second language**

In multilingual classrooms, learners have varying levels of proficiency in both English and mathematics. According to Slavit & Ernst-Slavit (2007), English Second Language (ESL)
learners have to build their oral English skills, acquire reading and writing skills in English as well as keep up with their learning in mathematics. Moschkovich (1996) argues that for ESL learners, learning mathematics in English involves making multiple connections across several discontinuities. Essien (2010, p. 171) claims that, “any attempt to improve the language proficiency of learners with the aim of improving academic proficiency should be done in such a way that basic interpersonal communicative skills and cognitive-academic language develop concurrently”. Slavit & Ernst-Slavit (2007) suggested that teachers can help learners to develop proficiency in English as well as access the mathematics register by:

- **Language clarification.** The teacher explains clearly the meaning of the mathematical terms and expressions to learners.
- **Creating mathematical language banks,** where the focus is on meaning, form and use of terms or expressions.
- **Carry out whole class or small groups discussions** so that learners take ownership of mathematical language by reporting back.
- **Demonstration/modelling** how to express mathematics or use mathematical terms.

In the case mentioned above the teachers’ main/home language is English. While creating mathematical language banks, demonstrating and carrying out group or whole class discussions can be easily executed by a professional language clarification can be a challenge to English second language speakers. Diaz-Rico & Weed (2006) suggested that use of the following strategies can make English second language learners able to access the same high quality academically challenging content that the native English speakers receive:

- **Alleviate potential comprehension problems** by speaking slowly, writing critical vocabulary on the board and avoiding slang.
- **Lesson planning that includes multicultural content** so as to recognise the learners’ backgrounds and diverse perspectives.
- **Allow the learners to use their first language among themselves (in small groups)** as a resource and support.
- **Higher order questioning** that promotes critical thinking

**Conceptual framework of study**

This study is informed by Kilpatrick, Swafford and Findell’s (2001) theory of teaching for mathematical proficiency which states that teaching for mathematical proficiency is a complex activity involving five interrelated components. The five components for teaching proficiency are conceptual understanding of core knowledge, fluency in instructional routines, strategic competence, adaptive reasoning and productive disposition.

**Conceptual understanding of core knowledge** is whereby teachers make connections within and among their knowledge of mathematics, their learners and pedagogy. Hiebert & Lefevre (2001) argue that if a person has conceptual understanding of a concept, she/he can use it flexibly. Thus, teachers with conceptual understanding of core knowledge can deliver a lesson with easy, confidence and flexibility to accommodate learners with different learning styles. **Fluency in instructional routines** enables teachers to readily draw upon them as they interact with learners in teaching mathematics. Routines can be grouped into mathematical activity and classroom management. Mathematical activity routines include knowing how to
deal with learners who lack critical skills and how to respond to learners who demonstrate serious misconceptions or gives an answer that the teacher does not understand. Classroom management routines include how to get the class started and procedures of checking, collecting and correcting homework. Teachers with access to a range of routines know when they are appropriate, can adapt them to fit different scenarios and can apply them flexibly. Strategic Competence is the ability to formulate, represent and solve mathematical problems. Teachers who have acquired strategic competence can plan and implement effective instruction. This component also involves solving problems that arise during instruction. Adaptive Reasoning refers to the capacity for logical thought, reflection, explanation and justification. Teachers with adaptive reasoning can justify and explain their teaching strategies and also reflect on those strategies with an aim of making them more effective. Reflection is a critical requirement for improving one’s practice. Finally, Productive Disposition is where the teacher has habitual inclination to see teaching, learning, improvement of strategies and mathematics as useful, worthwhile and sensible. This component can develop in teachers as they analyse what goes on in their classes and listening to their students.

The five components of teaching for mathematical proficiency will be useful in this study as an instrument to examine the strategies used to teach functions by foreign educators. Conceptual understanding of core knowledge, adaptive reasoning and productive disposition components was used to measure of the how the teachers prepare and evaluate their lessons. Fluency in teaching routines and strategic competence was used to analyse and measure the effectiveness of the strategies used for teaching functions so as to encourage learners’ participation in mathematical discourse and develop mathematical proficiency.

The study
The study is a qualitative case study of two foreign educators in teaching functions and relationships to Grade 11 classes. Lesson observations were conducted with the teachers and tape-recorded. This was followed by semi-structured interviews focusing mainly on teachers’ practices in the lesson observed.

Sample
The study was carried out at a public school in Johannesburg. The student body is made up of about two thirds black and one third coloured learners. The coloured learners either speak Afrikaans or English at home while there is a whole spectrum of the nine home languages among the black learners. Therefore any given class at the school presents the features of a multilingual classroom. The Grade 11 classes who participated in the study were chosen by each teacher from their work load for their convenience. The two teachers were chosen because they were the only other foreign teachers in the mathematics department.

Strategies used by Farai to teach the hyperbola function.
There were six distinct instructional strategies in Farai’s lesson, viz, linking previously learnt material to new concept (re-capping), strategic sequencing, exploration over well-chosen example space, adjusted speech, revoicing and group dynamics. What follows is an analysis of how each of the strategies was used in the lesson.

Linking previously learnt material to new concept
This strategy refers to a process of always bringing in previously learned material to build on the concept at hand so that learners have a base knowledge to start with. Hence this strategy
promotes constant reinforcement of learned structures and formation of connections among pieces of information in the learner’s brain leading to conceptual understanding (Hiebert & Lefevre, 2001; Kilpatrick et al., 2001). There were five instances where Farai employed this strategy in his lesson. He used this strategy to reinforce the previously learnt concept. In another case he used this strategy to correct misconceptions as shown in line 8 to 11 in Extract 1 below.

Extract 1
1. Teacher: 4 divided by 0, what do we get?
2. Learners: zero
3. Teacher: Zero? Who can say better?
4. Learner1: Undefined.
5. Teacher: Any number divided by zero is undefined. Are you there?
6. Learner2: zero
7. Learner3: It’s not allowed.
8. Teacher: Any number divided by zero is undefined. You cannot say it’s not allowed. In primary school they used to say any number divided by zero is not allowed. We are not supposed to divide by zero. Are you there? But zero divided by a number, what does it give us?
9. Learners: zero.
10. Teacher: zero. Are you there? Now, 4 divided by 1, what do we get?
11. Learners: 4

The chances of making connections among pieces of knowledge (Hiebert & Lefevre, 2001) increase as learners correct their misconceptions, thereby promoting the development of conceptual understanding. Farai also used this strategy to make connections among concepts, for example when he was dealing with properties of the hyperbola as illustrated in Extract 2 below.

Extract 2
1. Teacher: So, if my k is positive, the graph will be in this quadrant (drawing in 1st quadrant) and this quadrant (drawing in 3rd quadrant). Are you there? And we need an axis of symmetry. What will be the axis of symmetry in this case?
2. Learner1: y = x
3. Teacher: y = x, no. it will be this one (referring to line y = x). What is an axis of symmetry guys?
4. Learner4: A line that divides the object.
5. Teacher: it divides the object into 2 equal parts. Are you there?

In lines 3 to 5 Farai wanted the learners to understand symmetry and also name the axis of symmetry. Therefore in using this strategy the teacher displayed understanding of core knowledge, strategic competence as well as fluency in instructional routines.

**Strategic sequencing**

Sequencing refers to the order of presentation of concepts in delivering the lesson. From the lesson description above, it is clear that Farai takes time to think and plan for the lesson. In the post-observation interview, when asked the question: Before you teach a topic, what do you normally do to prepare for the class? He replied:

*Farai:* The first one is to check the level of the students, how I can introduce the subject, ok. And bear in mind the outcomes from the work schedule, what I should achieve at the end of the topic, ok. So I look at the work schedule, I look at what I
should address and then look at what the book is saying and try to find a way, a method that is appropriate according to the learners’ level.

As a result of this planning, Farai started from the known, in this case, the parabola to the unknown which is the hyperbola. Generating the table of values in whole class discussion ensured engagement of learners in the work as well as encouraging learner participation in mathematical discourse. In whole class or small group discussions, learners take ownership of mathematical language and grasp concepts as they make contributions or report back (Slavit & Ernst-Slavit, 2007). The learners discovered for themselves the shape of the hyperbola as they plotted the graph although most of the learners had difficulties joining points with an undefined region in the middle. Farai gave the learners a class activity to let them practice and internalise the properties of a hyperbola. I therefore can say the sequencing in Farai’s lesson promoted the development of an interconnected body of knowledge in learners (Kilpatrick et al., 2001) which leads to attainment of mathematical proficiency. Farai showed developed strategic competence and fluency in instructional routines in sequencing the lesson in a connected way.

**Exploration over an example space.**

Exploration in this study refers to the process which involves testing values from an example space by substitution into a formula or mathematical model to see what happens. As learners discover what happens for themselves, it will be easier for them to remember and use it in future (Polya, 1962). This strategy encourages the development of mathematical disposition and adaptive reasoning as it triggers reflection and wanting to know what happens in different situations. An example of one of the instances where Farai used this strategy in his lesson is shown in Extract 3 below.

**Extract 3**

Teacher: Let’s put a few values of \( x \) and see what will happen there (teacher draws the table below on the chalkboard).

<table>
<thead>
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<th>( x )</th>
<th>-2</th>
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</thead>
<tbody>
<tr>
<td>( y )</td>
<td></td>
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</table>

For example, if \( k \) is 4 in the equation \( y = \frac{k}{x} \), we have \( y = \frac{4}{x} \). Suppose, \( x = -2 \). What is \( y \)?

Learners: -2

In well-resourced schools, teachers use technology to do this kind of exploration. In this lesson Farai adapted the instructional strategy to suit his situation of no access to resources which exhibits fluency in instructional routines (Kilpatrick et al., 2001) and also prevents potential comprehension problems (Diaz-Rico & Weed, 2006).

**Adjusted speech**

According to Slavit & Ernst-Slavit (2007), adjusted speech includes changing patterns of speech and voice tone, paraphrasing often, clearly indicating important ideas and limiting asides. In the lesson observed, Farai altered his voice tone depending on what he wanted to portray. He raised his voice when he wanted to draw the learner’s attention on something or emphasise important points. For example in Extract 1 line five, his voice was raised to emphasise the point that any number divided by zero is undefined. In Extract 4 line 6-10, Farai attempted to paraphrase the question: “what determines the shape of the graph?” but
was clearly failing to make the learners understand his question until he repeated the question slowly in line 5.

Extract 4

1. Teacher: Ok, this way (drawing a parabola with a minimum point on the chalkboard). Ok, what makes you say it should look this way? What do we know about the shape? What are you calling the shape?
2. Learners: Parabola.
3. Teacher: Yaah, a parabola. But what determines the shape of the graph?
4. Learners: (make a chorus unclear answer)
5. Teacher: You don’t understand that’s why you don’t answer the question. What determines the shape of your graph (talking slowly)?
6. Learners: \( \alpha \)

Therefore speaking slowly encouraged learner participation in mathematical discourse in this case by promoting understanding of the question so that they can respond to it. Extract 4 also highlights the fact that English second language educators may have a challenge with language clarification but access to other strategies will alleviate the problem.

**Revoicing**

Revoicing as a pedagogical practice involves repeating what the learner or student has said, most often, using the appropriate mathematical language. From my observation, Farai used revoicing when he wanted to capitalise on the learner’s response. For example he revoiced in Extract 2 line 3 in order to build on the learners’ responses while in line 5 Extract 2 he used it to emphasise the idea of symmetry. In Extract 1 line 10 Farai used revoicing to check if the class was on the same page. The varied ways in which Farai used this strategy in the lesson shows fluency in instructional routines (Kilpatrick et al., 2001) as well as encourage learner participation which promotes the development of mathematical proficiency.

**Group dynamics**

The class sat in the front rows of desks even though there were more desks than the number of learners suggesting that the teacher prefers the learners closer to him. This creates a sense of belonging in learners and encourages learners to speak freely with the teacher or even think aloud, which was evident in the lesson. For example, in Extract 1 lines 6 and 7 the learners were thinking aloud. The furniture arrangement also promoted group discourse as learners were not far from each other, which they did during the class activity. Since the groups were probably according to friendship some of the learners were able to fall back on their home language in their small group discussions as a resource and support in discourse (Moschkovich, 1996). Therefore the small group and whole class discussions which took place promoted learner participation in mathematical discourse.

**Strategies used by Jabu to teach the exponential function.**

Six instructional strategies emerged from observing Jabu’s lesson on the exponential function which are linking previously learnt material to new concepts, strategic sequencing, exploration over a well-chosen example space, predicting mathematically, adjusted speech and revoicing

**Linking previously learnt material to new concept**

Like Farai, Jabu also started from the known to the unknown. For example, in Extract 5 below, Jabu used previously learnt material as base knowledge for this lesson.

Extract 5

1. Teacher: Today we are going to look at the exponential function. This is expressed in the form \( y = a^x \) (unclear words).
2. Right, we said $y = \alpha^x$ is the general equation of an exponential function. But we want to choose a particular function where the $\alpha$ is given, for instance, in the case $y = 2^x$.

3. Now, as normal, we know that $x$ is the independent variable in the expression. So, every value of $y$ is going to depend on the value of $x$. First of all, we start when $x = 0$. What is $y$ when $x = 0$?

4. Learners: (gave a chorus unclear answer)

5. Teacher: That is; $y = 2^0$. What is it?

6. Learner1: zero

7. Learner2: $y = 1$

8. Teacher: $y = 1$. Leave your calculators. It’s something that you are supposed to know without using a calculator because any number raised to the power of zero is 1 anyway. But some of you want to use the calculator. So, that is 1, for any number raised to the power zero is equal to 1.

9. So, the $y$-intercept is 1 (some learners also say 1).

10. So we know that the graph will intercept the $y$-axis at $y = 1$. Now let’s check and see the $x$-intercept. This is $y = 0$. Where do we get our $x$-intercept? What’s the value of $y$ when $x$ is ..., $y = 0$. But now in this case, let’s take $y = 2^x$ and see if we can get the $x$-intercept. The $x$-intercept is found when $y = 0$. That’s what we know by now. We say $0 = 2^x$. Let’s see whether we can get the value of $x$ in this case (learners are given about 1.5 mins to calculate). I will allow you to use a calculator (1 more minute is given).

In line 3 above, Jabu used the previous knowledge on variables to explain why they can predetermine the values of $x$. He also applied the procedure to find intercepts in line 10 as he said, the $x$-intercept is found when $y = 0$. That’s what we know by now. In line 8 he recapped the law of exponent which reinforces the concept and promotes conceptual understanding (Willis, 2008).

### Strategic sequencing

In interview Jabu showed that he gives thought to his practice by carefully planning his classroom actions. On answering the question: Before you teach a topic, what do you normally do to prepare for the class? He replied:

Jabu: *I check the aspects that are needed for me to teach what I am going to teach, especially the background knowledge, the assumed knowledge, what they (learners) have done before and the relevance to what I am going to teach in that particular lesson. As I prepare for that, I start from known to the unknown*

The definition of the exponential function led to an exploration to establish the trend of the function which in turn revealed the shape and other properties of the function. Therefore it can be said that the sequencing in this lesson promoted a deep understanding of the exponential function and procedural fluency as the learners substituted values into the equation and establish a trend. Also, Jabu displayed understanding of core knowledge by making connections, strategic competence in planning and implementing those plans as well as fluency in instructional routines by knowing when the strategies are appropriate.

### Exploration over a well-chosen example space

Jabu used the exploration strategy most often in his lesson for learners to determine the trend of the exponential function in different equations. For example, in introducing the exponential function as illustrated in extract 5 lines 3 to 5 above, Jabu used it to make the function concrete for the learners.

Jabu later used the exploration method to determine the trend of the function which enabled the learners to sketch the graph as shown in Extract 6 below.
Extract 6

1. Teacher: Now let’s look at the trend of the graph. This is how we check the trend of the graph.
2. As x gets bigger and bigger, I want you to check what happens to y. As x gets smaller and smaller, I want you to check what happens to y.
3. X can take a negative value; it can take a positive value. I want all of us to check and see what happens as x gets bigger and bigger and as x gets smaller and smaller. Let’s check that out (teacher moves around the tables checking progress).
4. You can use 2 to 3 values negative and 2 to 3 values positive and see what happens. Let’s take for instance, x = 1; 3; 6 or whatever but it must get bigger and bigger, and let’s see what happens.
5. Let’s do a quick check. As x increases, what happens?
7. Teacher: Ha? Y decreases?
8. Learners: Y increases!
9. Teacher: I thought y increases because $2^1 = 2$. $2^2$ is what?

Jabu wanted learners to find out the behaviour of the function at zero, negative and positive values of x which promotes conceptual understanding of the function’s behaviour. In line 3 to 4 of Extract 6 Jabu gave the learners a large example space in which to choose values to determine the trend of the function. He gave the learners freedom of choice which promotes development of decision making skills as well as adaptive reasoning (Kilpatrick et al., 2001). In line 8 of Extract 6, learners were able to shout out the answer with confidence and conviction because they had discovered the trend on their own (the elation that comes with discovery). When asked the question: why did you use the exploration strategy to deliver this lesson? Jabu defended his choice by echoing Polya’s (1962) sentiments that it is easier to remember what one has discovered as is shown in extract 7 below.

Extract 7:

Jabu: As they do the substitution, there is discovery that takes place in their minds and it will be easier for them to remember what takes place in terms of what happens to an exponential function particularly when we look at the trend of the function.

This strategy also promotes procedural fluency as learners repeatedly substitute values into a formula (Kilpatrick et al., 2001). Thus the teacher can skilfully adapt and implement instructional strategies effectively even though the school is under-resourced.

Adjusted speech

Just as Farai did, Jabu altered his voice tone depending on what he wanted to portray. In many cases it was to draw the learner’s attention from their individual exploration for him to address the whole class. He was alternately encouraging and putting pressure on the learners to carry out his instruction as shown in the Extract 6 lines 1 to 5 above. His voice tone was particularly higher in line 2 than line 1 to emphasise the important point while it was a lower encouraging voice in lines 3 and 4. In line 5 the voice increased slightly to put pressure on the learners to get the job done. Jabu also paraphrased often as shown in Extract 6 lines 3 to 4 to make sure that the learners understand what he wants them to do. Thus the adjusted speech encouraged learners to participate in the class discussion as shown in line 8 which promotes access to mathematical register (Moschkovich, 1996; Slavit & Ernst-Slavit, 2007) as well as develop mathematical proficiency. In employing this strategy, Jabu displayed strategic competency as he chose how to deal or respond to the learners’ contributions.

Re-voicing
Re-voicing learners’ contributions make the learners feel that their contributions are important and are encouraged to contribute more (Slavit & Ernst-Slavit, 2007). In the three cases where Jabu re-voiced, it was to capitalise on the learner’s answer as shown in Extract 5 lines 6 to 8 above. In line 6 to 8, the teacher ignored the wrong answer and re-voiced the correct answer to explain why it is correct as well as to reinforce the law of exponents that was previously learnt. The teacher’s decision may have been to avoid being side tracked from the lesson’s focus but the wrong answer could also be a result of serious misconceptions which needed to be addressed. However, according to Kilpatrick et al. (2001), teachers need to decide whether or not to follow a learner’s idea depending on the goals for the lesson. Thus, Jabu displayed strategic competence in choosing how to deal with the learners’ contributions.

Group dynamics
Jabu used whole class discussions as a strategy to encourage learner participation in mathematical discourse as shown in Extract 5 lines 6 to 9 and extract 6 lines 5 to 9 for example. However, the class sat in neat rows of desks facing the chalkboard with ample space for the teacher to move between them. The furniture arrangement suggests that the teacher prefers order and learners to work individually as the seating arrangements does not encourage pair or group work. However, some of the learners worked in pairs during the class activities and the teacher allowed it. The pairing up that occurred even when the teacher did not specify how the work should be done (individually or group work) suggests that some learners need peer support in learning.

Predicting mathematically
Predicting mathematically involves using an existing trend to forecast future values or behaviour. There were instances where Jabu used this strategy as shown in extract 8A and 8B.

Extract 8A

Teacher: Let’s look at another one whereby a is no longer 2. Our $a$ is $\frac{1}{2}$. Are we going to get a different scenario when we look at that? Now we can quickly look at the intercepts. Again, when $x = 0$ we get the $y$-intercept. In $y = \left(\frac{1}{2}\right)^x$ when $x = 0$, what is the $y$-intercept?

And again: Extract 8B

Teacher: The $x$-axis is the asymptote there. But now I want you to check to see what happens when $x$ gets bigger and bigger what happens to $y$ and as $x$ gets smaller and smaller what happens to $y$. let’s see the trend of the graph. Can you check the trend and then draw the graph? Is it going to be the same as the graph we drew before or is it going to be the inverse or there is going to be some slight difference? Let’s draw the graph now (teacher moves around the tables checking progress).

In 8A he asked learners, “Are we going to get a different scenario when we look at that?” This kind of question forces learners to reflect on the work done for them to be able to predict what will happen. In line 3 to 5 of extract 8B he also gave learners an example space to make a prediction from, which encourages the development of adaptive reasoning.

Farai and Jabu showed high levels of reflection and productive disposition on their practice. According to Kilpatrick et al. (2001) reflection is a critical requirement for improving one’s practice. They all agreed that there was room for improvement even though they think that their lessons were successful. Shown in the extract below are their responses to the question: If you were to teach this lesson again (or next year), would you do anything differently?
*Farai:* yes, there is always innovation depending on the learners. Depending on what I want them to achieve. I can do it in many ways. You can art by giving them, maybe a question which is not related to the hyperbola for example let’s say you teach them about the quadratic equation. Look at the shape and then you introduce this one, so that they can see the difference. You can teach depending on what you want to achieve.

*Jabu:* ...As I alluded to before, that maybe I would use group work, maybe I would use other functions to compare between the new function that they are learning. Well, it depends on the kind of learners I will be teaching. In future, I might not be teaching the same kind of learners. So, it might be quicker or slower.

Thus, the two teachers do not think that what they did is the only effective way to teach those particular lessons. It is also evident that the teachers reflect on their practice and are therefore more likely to improve their teaching than a non-reflective teacher.

**Conclusions and recommendations**

The findings reveal that the two teachers have access to a range of instructional strategies. Each of the teachers used a total of six strategies in one lesson. They moved from one aspect of the topic to the other and the strategies were used appropriately. Kilpatrick et al. (2001) argue that expert teachers can apply a range of strategies flexibly, adapting them to suit the situation and use them appropriately. In this light, both teachers can be called proficient teachers.

The study established that the teachers used: linking previously learnt materials to the new concept, sequencing, predicting mathematically and exploration over a well-chosen example space, to promote the development of mathematical proficiency in learners. The analysis of results also revealed that the teachers encouraged learner participation in mathematical discourse by using re-voicing, adjusted speech and through regularities in the group dynamics to which they have attuned their learners. Hence, it can be argued that it does not matter whether or not the teacher speaks the learners’ main/home language as long as the teacher has access to a range of instructional strategies to alleviate potential comprehension problems. Sharing the same home language with the learners is only an added advantage. It is therefore recommended that when teaching multilingual classes (English second language learners) teachers should:

- Consider ways of linking the learners’ previously learnt material to the new work.
- Sequence their lessons intelligently to allow the learners to use previous material in the net activity/task.
- Adapt strategies known to be effective in certain situations to suit their own circumstances.
- Strive to be proficient in English themselves in order to help the learners to access the mathematics.

The scope of the study did not allow establishing whether there is a connection between the improved performances in mathematics with the presence of the foreign educators. However, while the study acknowledges that there is a whole spectrum of factors that affect learner performance it does not underestimate the power of strategies. It would be interesting to investigate whether the improved performance is connected to the presence of the foreign educators. If connected then investigating how the teachers were trained will be worthwhile.

**References**


Tensions in the transition from informal to formal geometry

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Abstract
The nature of Euclidean geometry as both concrete, in that it is linked to physical objects, and abstract, in that it is organised into an axiomatic system, creates interesting tensions that can be both productive and cause problems in the process of learning and teaching it. The National Curriculum Statement for Mathematics (South African Department of Education, 2003) for grades 10 – 12 in South Africa indicates grade 10 as the transition point from working with an informal study of geometry to a more formal study of geometry. In this paper I examine how a popular textbook for grade 10 Mathematics managed the tensions inherent in working with this transition point.

Introduction
The first substantial revision of the mathematics curriculum for grades 10 - 12 in South Africa post-apartheid resulted in the National Curriculum Statement for Mathematics (NCSM) which was published in 2003 and implemented in grade 10 in 2008 (South African Department of Education, 2003). Although the NCSM was substantially revised and replaced by the Curriculum and Policy Statement (CAPS) in 2012, the strong emphasis on transformation and redress that underlay the work on the NCSM makes it a particularly interesting curriculum to study. An interest in understanding the inter-relationship between strong social and pedagogical forces on school mathematics motivated a research project that examined the nature of geometry constituted in the NCSM and two textbooks written to align with this curriculum. As part of this study it emerged that the NCSM located grade 10 as the transition point between an informal study of geometry and a more formal study of geometry. In this paper I report on some of the findings in relation to how this transition was managed in one of the textbooks studied.

The nature of geometry
Geometry, in contrast to many other branches of mathematics is linked to physical objects and their representations (Niss, 1998) and so developed out of an understanding of physical space. Frege, in his work on the foundations of mathematics argued that arithmetic and analysis were founded in logic, but Euclidean geometry was not as it was based on an intuition of Euclidean space (Frege in Tymoczko, 1985). At the same time, Euclid’s elements are seen as the prototypical example of axiomatisation (Mammana & Villani, 1998). Herbst and Brach state that

“In the United States for more than a century, a course on Euclidean geometry has been justified as part of the high school curriculum primarily on the grounds that it provides a context in which students can encounter and learn the “art of mathematical reasoning”’’(Herbst & Brach, 2006, p74).

This notion is echoed by Galuzzi (1998) in his discussion on school geometry in Italy and implicitly in much of the research literature on the learning of proof in school mathematics which recognises that it has been largely restricted to the geometric setting (Hanna & Jahnke, 1996). In the study of geometry, objects are seemingly familiar and concrete, but are in fact unfamiliar and “unseeable”. For example, even young children are able to identify and
recognise a square, however the abstract geometric object “a square” is not something we can touch or hold. As Pimm (1995) says “Any physical or drawn square is not a square,” (1995, p57). Fischbein (1993) uses the term “figural concepts” to talk about geometrical figures. The term captures the notion that any geometrical figure possesses both “conceptual and figural characters” (ibid, p139). The figural character would be the spatial representation and the conceptual character the abstract properties governed by the object’s definition. Fischbein and Nachlieli (1998, p1195) argue that the highest level of geometrical reasoning is attained when “the figural and conceptual constraints are perfectly harmonized in what we have called a figural concept”. However they go on to state that the harmony between the figural and conceptual constraints does not imply they should be equally weighted. In fact the conceptual constraints need to control the reasoning about the geometrical figure. They argue that it is the figural component that allows for creativity and opens new directions for investigation, but that it is the conceptual constraints that must determine the logic and rigour of the investigation. The implications of this type of idea for the teaching and learning of geometry have occupied mathematicians and educators for many years.

**Van Hiele and the South African curriculum**

The discussion of the nature of geometry shows that it occupies a role that is at once concrete and practical and yet also highly abstract and theoretical. Fujita and Jones (2003, p47) argue that although this dual nature of geometry “should help teachers link mathematical theory to their pupils’ lived experience, in practice for many pupils the dual nature is experienced as a gap that they find difficult to bridge.” The difficulty learners have in dealing with dual nature of geometry has been well documented. In many instances this has involved looking at how learners move from working only with concrete shapes to seeing the same shapes as manifestations of a theoretical shape governed by its definition. Perhaps the most well-known and extensively used of these learning theories is that put forward by Pierre and Dina van Hiele (Mayberry, 1983). The Van Hieles identified five levels of geometric thought and suggest that learners need to move through these levels sequentially. These levels are visualisation, analysis, informal deduction, deduction and rigour. The type of geometry questions that South African learners have been expected to deal with in their final year of schooling are at the level of deduction (van Putten, Howie, & Stols, 2010). However a variety of studies in South Africa have shown that learners in South Africa are operating well below this level (Atebe, 2008; M. D. De Villiers, 2012; M. D. De Villiers & Njisane, 1987; Kotze, 2007).

The concerns raised by studies like these together with evidence of the very poor performance of learners in geometry in the school-leaving examinations meant that at the time of curriculum revision in South Africa there was a strong imperative to substantially alter the proposed learning trajectory in geometry. In this revision the Van Hiele theory of levels of thought was particularly influential. The geometric work proposed in the South African curriculum up to grades 9 focused on the first 3 Van Hiele levels (Feza & Webb, 2005). The NCSM for grades 10 – 12 was thus intended to help learners make the transition from informal deduction to deduction. When I interviewed members of the committee who had constructed the NCSM they mentioned that the work of Michael de Villiers had been particularly influential in helping them shape the geometric sections of the curriculum. Much of Michael de Villiers work has been strongly influenced by the Van Hieles. His published work in relation to the classification and definition of quadrilaterals (M. de Villiers, 1994, 1998), the role of definitions in geometry (M. de Villiers, 1996, 1998) and the use of
transformation geometry throughout all levels of the mathematics curriculum (M. de Villiers, 1993) has clear parallels in the NCSM. However the nature of the curriculum document is such that aspects that are discussed in depth in relation to theory and illustrated with practical examples in De Villiers’s papers are reduced to a single line in the NCSM. The strong foregrounding of a particular theory of learning geometry in the construction of the curriculum coupled with a subsequent lack of explicit discussion in the curriculum document about the thinking that underlay its construction sparked my interest in how the curriculum would be interpreted. I was specifically interested in how the aspects intended to manage the difficult transition between informal and formal geometry would play out. In this paper I report on an analysis of the relationship between informal and formal geometry in the best-selling grade 10 mathematics textbook written to comply with the NCSM. Although the NCSM contains work on area and volume, coordinate geometry and transformation geometry, in this paper I report specifically on the work related to the study of quadrilaterals. This work is indicated in the NCSM as follows:

<table>
<thead>
<tr>
<th>10.3.2 (a) Through investigations, produce conjectures and generalisations related to triangles, quadrilaterals and other polygons, and attempt to validate, justify, explain or prove them, using any logical method (Euclidean, co-ordinate and/or transformation).</th>
</tr>
</thead>
<tbody>
<tr>
<td>(b) Disprove false conjectures by producing counter-examples.</td>
</tr>
<tr>
<td>(c) Investigate alternative definitions of various polygons (including the isosceles, equilateral and right-angled triangle, the kite, parallelogram, rectangle, rhombus and square).</td>
</tr>
</tbody>
</table>

Figure 1. Extract from the NCSM (South African Department of Education, 2003, p.32)

In order to analyse the textbook I needed to find a theory that differentiated between informal and formal geometry. In the section that follows I describe the work of Houdement and Kuzniak that I drew on to create an analytic framework. Thereafter I describe how I shaped this work into a tool to analyse the textbook and the results that emerged from this analysis.

Theoretical framework: Houdement and Kuzniak’s three paradigms of geometry

Two French researchers, Houdement and Kuzniak have developed a framework for understanding geometry that distinguishes three paradigms of geometry. They argue that this theoretical frame has been developed via a theoretical analysis of philosophical, mathematical and didactical texts as well as being verified empirically. The three paradigms they distinguish are Natural Geometry (Geometry I), Natural Axiomatic Geometry (Geometry II) and Formalist Axiomatic Geometry (Geometry III) (Houdement & Kuzniak, 2003; Kuzniak & Houdement, 2002). In Geometry I (GI) the objects one works with are material objects (or drawings of material objects) and one makes deductions via experiment, perception and use of instruments. The correspondence with reality is the yardstick by which deductions in this paradigm are judged. In Geometry II (GII) one uses deduction within an axiomatic system. However the axioms are based in an attempt to provide a model of the space around us. Traditional Euclidean geometry would be a typical example of GII. Geometry III (GIII) is an
axiomatic system where no attempt is made to maintain a link to reality. Kuznik and Rauscher (2011) argue that these three paradigms help us to clarify the different meanings that can be given to the term geometry. At school level we work largely within GI and GII. Houdement (2007) describes the difference between the two as being evident in the objects (physical versus conceptual), techniques (material tools versus production of conjectures and logical validation) and validation mode (conformity to reality versus deduction from logical reasoning). Although the paradigms are distinct there are clearly links between them. Expert geometry users are able to move easily between the paradigms with awareness of the strengths and limitations of each. However for a student the initial move from GI to GII requires a dramatic shift in the mental perspective on the geometric object despite the visible image not having changed at all (Houdement & Kuzniak, 2003). In addition to this difficulty it is possible for student and teacher to adopt two different paradigms and hence miscommunicate (Houdement & Kuzniak, 2003; Kuzniak & Rauscher, 2011).

The distinction between GI and GII offered a productive way to examine the work in the textbook relating to informal and formal geometry.

**How the textbook was analysed**

I analysed the chapter on quadrilaterals in the best-selling grade 10 textbook written for the NCSM, Classroom Mathematics Grade 10 (Laridon, et al., 2004).

In order to chunk the textbook chapter into analysable units I used the notion of blocks that was developed in the TIMSS textbook study (Valverde, Bianchi, Wolfe, Schmidt, & Houang, 2002). In the TIMSS study blocks are described as either narrative elements which tell stories, state facts and principles through narration (ibid, p141) or activity elements which “prescribe a set of actions that students are intended to perform outside of the world of the textbook” (ibid, p142) or questions sets or worked examples. Blocks tend to be well-delineated by the textbook itself through features like headings or numbering. In addition it was possible to identify when one block stops and another starts when there is a change of function. For example, when an explanation of a concept finishes and an exercise set starts, one can see one block end and another block start. In order to analyse the relationship between informal and formal geometry I analysed each block in the textbook in relation to two aspects.

The first aspect was the apparent dominant paradigm of geometry that the block displayed. To do this I developed the following indicators drawn from the work of Kuzniak and Houdement and research based on their theory. These are shown in table 1 below.

I specifically chose to include the adjective “apparent” in describing the apparent dominant paradigm because, in the process of analysing the blocks, I came across instances in which the nature of deduction required appeared to be GII, but where the necessary groundwork to operate in GII in that instance had not been provided. Thus the word “apparent” indicates that I am not making a claim that, in the case of blocks indicated as belonging to GII, the necessary definitions and axioms are in place to enable the work required in the paradigm.

The second aspect I examined in the textbooks was whether there was any teaching in the textbook directed at orienting learners towards the features of, and differences between, the 2 paradigms. In particular I wanted to see if the following were present:
- Discussion about elements of geometry in GI e.g. visualization, construction and measurement, investigation and conjecturing:
- Discussion about elements of geometry in GII e.g. definition, proof, counterexample, axioms, theorems and axiomatic systems

### Table 1. Indicators for GI and GII

<table>
<thead>
<tr>
<th>Nature of objects</th>
<th>GI is apparent dominant paradigm</th>
<th>GII is apparent dominant paradigm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature of tools</td>
<td>Objects are physical. Drawings are used as objects and are what is measured, manipulated or drawn to come to conclusions about properties.</td>
<td>Objects are theoretical. Drawings are used to support reasoning.</td>
</tr>
<tr>
<td>Nature of tools</td>
<td>Drawing instruments (for accurate construction), measuring instruments, manipulation or computer software present (or implied)</td>
<td>No physical tools present or implied</td>
</tr>
<tr>
<td>Nature of deducation and validation</td>
<td>Validation and deduction based on perception or use of instruments or through experimentation.</td>
<td>Logical deduction required from a set of facts.</td>
</tr>
</tbody>
</table>

#### Findings
The chapter on quadrilaterals contained 39 blocks. 8 of these blocks were not appropriate for analysis in terms of the geometric paradigm. These were blocks like the following narrative block “You will now find out about the properties of the rhombus, parallelogram, kite and trapezium” which simply orient learners to the work that is coming and do not indicate a particular paradigm. Table 2 below show the distribution of the remaining 31 blocks in relation to the paradigms. One block contained both GI and GII and so was counted in both. Table 2 also indicates the number of blocks in which there is discussion about the nature of the paradigms or about the elements of paradigm.

### Table 2. The number of blocks per paradigm in the chapter on quadrilaterals

<table>
<thead>
<tr>
<th></th>
<th>GI</th>
<th>GII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparent dominant paradigm</td>
<td>10</td>
<td>22</td>
</tr>
<tr>
<td>Discussion about nature of paradigm or about elements of paradigm present</td>
<td>0</td>
<td>9</td>
</tr>
</tbody>
</table>

This summary indicates that GII was the apparent dominant paradigm in the majority of the blocks and that is was the only paradigm that was discussed. In the blocks in which the elements of GII were discussed the issues looked at were proof, axiomatic systems and definitions. However, in almost all blocks where definitions were discussed axiomatic systems were discussed too.

The summary indicated that it would be useful to look in greater depth at two aspects: the
ways in which GI was used in the chapter and at the link between GI and the elements of GII that were specifically discussed (proof and definitions and axiomatic systems)

The uses of GI
Out of the 10 blocks in which GI is the apparent dominant paradigm, 5 have modelling as the main focus and 4 relate to the statement in the curriculum that asks that learners produce conjectures and generalisations about quadrilaterals through investigations. The 10th block is an exercise set that contains work in both GI and GII.

Modelling
This occurs in 5 blocks. Three out of the 5 blocks are in blocks entitled “did you know”. These blocks are not central to the development of the work of the chapter. They illustrate how some of the facts about quadrilaterals can be applied to real-world scenarios. The 4th and 5th blocks are activities. In one, learners are asked to explore how a carpenter might create a rectangle. In the other, mechanical linkages are explored. The learners create a physical model of a car jack and explore the action of the linkages. They are then asked to prove the conjecture they make on the basis of this physical exploration. We see in these blocks less of a use of GI to enter into GII, but rather illustrations of how the geometric facts that have been established apply in real world situations.

Investigation
GI is the dominant paradigm in the first two activities of this chapter. The example below shows what each of the questions in these activities asks the learners to do:

1. a) Draw a square such as ABCD, with length of side 10 cm.
   Cut the square out.
   b) Use the cut-out square to investigate as many of the properties of the square as possible. Measure lengths and angles or fold the cut-out as you may decide.
   Write down what you find out about:
   (i) the sides of the square
   (ii) the angles of the square
   (iii) the diagonals of the square
   (iv) the number of axes of symmetry the square has
   (v) the order of rotational symmetry of the square.

Figure 2. Extract from Laridon et al (2004, 336)

This question is done in the case of the square. The questions that follow ask the learners to repeat the process for the rectangle, rhombus, parallelogram, kite and trapezium. The learners are asked to record their results by ticking off properties in the following table.

This activity (and the ones that follow it) are presented as investigations. However the investigation is tightly prescribed and learners are told exactly what to do and what to find out about. In addition the investigation is static. By this I mean that, although the properties of square, rectangle, rhombus, parallelogram, kite and trapezium are each investigated in turn, there is no sense in which the geometric interrelationships are explored. For example there is no investigation that allows one to see that, although in a parallelogram the diagonals are not necessarily equal, if one “pulls it upright” into a rectangle this creates equal diagonals
because all the interior angles are the same size.

<table>
<thead>
<tr>
<th>No.</th>
<th>Property</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>All sides are equal</td>
</tr>
<tr>
<td>2</td>
<td>At least two pairs of adjacent sides are equal</td>
</tr>
<tr>
<td>3</td>
<td>Both pairs of opposite sides are equal</td>
</tr>
<tr>
<td>4</td>
<td>At least one pair of opposite sides is parallel</td>
</tr>
<tr>
<td>5</td>
<td>Both pairs of opposite sides are parallel</td>
</tr>
<tr>
<td>6</td>
<td>Interior angles sum to 360°</td>
</tr>
<tr>
<td>7</td>
<td>All angles are right angles</td>
</tr>
<tr>
<td>8</td>
<td>At least one pair of opposite angles is equal</td>
</tr>
<tr>
<td>9</td>
<td>Both pairs of opposite angles are equal</td>
</tr>
<tr>
<td>10</td>
<td>Diagonals bisect each other</td>
</tr>
<tr>
<td>11</td>
<td>At least one diagonal is bisected at right angles</td>
</tr>
<tr>
<td>12</td>
<td>Both diagonals are bisected at right angles</td>
</tr>
<tr>
<td>13</td>
<td>Diagonals are equal in length</td>
</tr>
<tr>
<td>14</td>
<td>Diagonals bisect at least one pair of opposite interior angles</td>
</tr>
<tr>
<td>15</td>
<td>Diagonals bisect both pairs of opposite interior angles</td>
</tr>
<tr>
<td>16</td>
<td>All angles between diagonals and sides are 45°</td>
</tr>
<tr>
<td>17</td>
<td>Number of axes of symmetry</td>
</tr>
<tr>
<td>18</td>
<td>Order of rotational symmetry</td>
</tr>
</tbody>
</table>

**Figure 3. Extract from Laridon et al (2004, 337)**

The investigation of a particular example of each of the special quadrilaterals is assumed to hold true for all examples of that special quadrilateral i.e. generalisation based on experimentation with a single example is allowed. The list of properties learners need to tick off is prescribed. Learners cannot, for example, record as a property for rectangles that they have “two long sides and two short sides” which, based on a prototypical example of a rectangle would be a natural observation to make.

This list of properties plays an important role in the rest of the chapter. The properties are treated as established fact and the development of certain proofs and definitions of the special quadrilaterals rely on it. These activities thus can be seen from two perspectives. Firstly they take place in GI and use investigation to produce a list of properties of the special quadrilaterals. But secondly this list of properties is implicitly controlled by a GII definition of the special quadrilaterals and, as will be discussed in the sections that follow, treated as if they are facts that can be used within the GII paradigm.

The other 2 blocks in which GI is the apparent dominant paradigm focus on work using coordinate and transformation geometry. This work is based on calculating lengths or gradients of specific line segments to make conclusions about the shape. For example,

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4 For ease of reference I will use the term “special quadrilateral” to refer to squares, rectangles, rhombi, parallelograms, kites and trapezia.
Of interest to note here is that although the curriculum stipulation is “Through investigations, produce conjectures and generalisations related to triangles, quadrilaterals and other polygons, and attempt to validate, justify, explain or prove them, using any logical method (Euclidean, co-ordinate and/or transformation)” (South African Department of Education, 2003, p. 32) this has not been realized here. Again we see that any “investigation” is strongly prescribed. The location of the work using coordinate and transformation geometry entirely in GI mitigates against it being used to make more general claims. In addition we see here ambiguity about what needs to be used to identify special quadrilaterals: learners could work from an informal GI idea of a prototypical image of that special quadrilateral or they could work from the list of properties generated.

The move into GII

Proof

After the initial activities in GI that lead to the list of properties, the move to an apparent dominant paradigm of GII is immediate. Learners are told: “In this section you will do calculations and proofs based on the properties of quadrilaterals.” (Laridon et al, 2004, p339) In most of the questions that follow learners are asked to explore relationship between properties e.g. questions that ask learners to prove statements similar to the one in this worked example:

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Figure 4. Extract from Laridon et al (2004, 345)

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Figure 5. Extract from Laridon et al (2004, 340)
The instructional narrative in this section provides the following information about proof:

![General discussion](image)

**General discussion**
- Giving reasons at each step is a way of explaining how you get from one step to the next in your solution.
- It is important to work only from what is given when providing a proof or doing a calculation.
- In Example 2, you cannot assume that the quadrilateral is a parallelogram even though it looks like it is. You could claim that the properties of quadrilaterals show that when both pairs of opposite angles are equal, we have a square, rhombus, rectangle or a parallelogram. All of these figures have opposite sides parallel and so $AB \parallel DC$ and $AD \parallel BC$.
- The proof given for Example 2 relies on basic known and accepted geometrical facts recorded in Chapter 3.

Figure 6. Extract from Laridon et al (2004, 340)

At one level this instructional narrative signals a clear move into GII and sets out the importance of not making assumptions about a shape just because of how it looks and of making logical deductions from one step to the next. On the other hand it places the list of properties that has been generated in a GI paradigm as definitive.

The statement “You could claim that the properties of quadrilaterals show that when both pairs of opposite angles are equal, we have a square, rhombus, rectangle or a parallelogram” is based on the assumption that the list of quadrilaterals in the table is complete. It makes the assumption that there is no other quadrilateral that has both pairs of opposite angles equal. And whilst this is true, it requires proof and the required proof is what is shown in figure 5 above. Thus the recourse to the work in GI, when taken to its logical conclusion, results in a circular argument.

There is a further problem in the question that asks learners the following:

5. Given that $BD$ bisects $\overline{DC}$, prove that $ABCD$ is a square.

![Figure 7](image)

Figure 7. Extract from Laridon et al (2004, 342)

In order to do this, learners must make assumptions about what it means to prove something is a square. As the notion of square exists only in a GI paradigm at this point it is uncertain what it would take to produce such a proof.

Thus we see that, because the first introduction to producing the kinds of proof which have the logical deductive format of GII relies strongly on a list of properties generated in GI (but implicitly governed by definitions arising in GII), there is a conflation of the two paradigms.

**Definition and axiomatic systems**
The instructional narrative shown in figure 8 below signals a change in focus and from this
point to the end of chapter the focus is on the process of defining the special quadrilaterals and organising them into a logical axiomatic system.

As suggested in the instructional narrative, in the activities and exercises that follow learners are asked to explore which of the properties from the table of properties can be used to define each of the special quadrilaterals. They then investigate properties the quadrilaterals have in common and properties that distinguish the quadrilaterals from each other. They then choose particular properties to define different types of quadrilaterals and see how the other properties can be derived from these.

This type of defining is common in mathematics. The textbook attempts to recreate this process and give learners an experience of building an axiomatic system. However recreating this process in a school mathematics textbook is a difficult task that offers layers of logical and pedagogical challenges that are illustrated in the textbook.

For example, in the first activity of the chapter learners are asked to cut out a rectangle which is 10cm by 7cm and by measuring or folding it explore the properties of the rectangle. Here learners are working in GI and are dealing with the properties of a very particular physical shape. In this paradigm it would acceptable to state that one noticed that the diagonals of this shape do not meet at right angles or that adjacent sides differ in length. However the notion of a rectangle is an established one in GII and, using the definition that exists in that paradigm, neither of the two properties mentioned would be acceptable. The textbook gets around this possible conflict by providing a list of properties that learners need to tick if they are present for a particular quadrilateral. “Problematic” properties (like the two mentioned above) are not included in the list. Thus the nature of the object explored in GI is implicitly controlled by its known nature in GII even though in the textbook it does not as yet exist in GII as it has yet to be defined. This tension, which we can view as working with an object that exists in GI, but not in GII for the learners and yet exists in GII in mathematics, is a hard one to work with.

In the activities and instructional narratives there is considerable discussion about how making different choices of defining properties could create either a partitional or hierarchical classification of the quadrilaterals. Learners are asked, for example
The curriculum asks that learners explore alternative definitions of quadrilaterals. Here the notion is of alternative definitions that lead to alternative classification systems and clearly alternative axiomatic systems.

However in addition to exploring alternative non-equivalent definitions learners are also asked to explore alternative equivalent definitions and to understand their place in axiomatic system. So for example, we see in figure 10 below the possibility for choosing different subsets from the list of properties as the definition of a kite.

This introduces very deep mathematical ideas. It brings up the important role of definition in mathematics and the strong link between definitions and the axiomatic system into which they fit. They need to understand that sometimes a different definition for an object actually creates a different object that fits into a different axiomatic system and at other times a different definition is in fact equivalent to the original definition and so refers to the same object.

Discussion
In this section I discuss two key difficulties that emerged from the analysis of the move from informal geometry (GI) into more formal geometry (GII) in the textbook. The first of these is the use of investigation and the second is the focus on the process of defining. Both of these
emerge from specific recommendations in the NCSM and have been argued for by authors using the work of the Van Hieles as support.

The idea that investigations can be a powerful support in developing geometric reasoning is not a new one. Fujita and Jones (Fujita & Jones, 2002, 2003) discuss geometric textbooks written by Godfrey and Siddons in the first half of the 20th century. In these textbooks carefully designed experimental tasks were aimed at helping learners to develop what Godfrey termed the geometrical eye. This he defined as “the power of seeing geometrical properties detach themselves from a figure” (Godfrey, 1910 as quoted in Fujita and Jones, 2003, p.47). Fujita and Jones argue that the design of the experimental tasks in Godfrey and Siddons’s textbooks focus learners’ attention on particular features of a drawing and thus help build their geometric intuition. They further state “Thus the place of these tasks in the teaching of geometry by Godfrey and Siddons is very important, not only for the sake of discovery, but also for the developing of the geometrical eye of students.” (Fujita & Jones, 2003, p56). In the textbook I examined the imperative to have a particular list of properties of the special quadrilaterals meant that investigations were tightly prescribed and so offered little in the way of developing a geometrical eye.

The type of defining done in the textbook is what de Villiers (1998) calls descriptive (a posteriori) defining. This refers to the fact that the concept and its properties are already known before it is defined. This contains an inherent tension. Although in mathematics the process of defining might start with an awareness of the existence an object which is then defined, the objects only exists mathematically once it is defined. The definitions of mathematical objects are carefully constructed (and adapted over time) to fit into a coherent mathematical systems. These ideas are echoed by Nachlieli and Tabach, who, using Vygotsky’s work on scientific concepts, state that “new objects make their way into mathematical discourse via their explicit definitions” (Nachlieli & Tabach, 2012, p11) and Fischbein who states

“The properties of geometrical figures are imposed by, or derived from definitions in the realm of a certain axiomatic system. From this point of view, also, a geometrical figure has a conceptual nature. A square is not an image drawn on a sheet of paper. It is a shape controlled by its definition (though it may be inspired by a real object).”(Fischbein, 1993, p141).

But at the same time many authors have highlighted the fact that definitions are not necessarily the best entry point for learners when meeting the object. (M. de Villiers, 1998; Freudenthal, 1973; Leikin & Winicki-Landman, 2000; van Dormolen & Zaslavsky, 2003; Vinner, 1991) In the case of geometric objects the inherent duality of the object allows us to introduce geometric objects to learners prior to defining them formally. As we have seen in the textbook this creates tensions. So properties learners are likely to ascribe to the prototypical representation of a parallelogram or rectangle are not included in the list. Learners then look at ways they can use these properties to define the special quadrilaterals. Thus although learners are ostensibly being given the opportunity to define the special quadrilaterals the existence of formal definitions for the objects in GII circumscribes the list of properties they are to produce for the object in GI. But almost paradoxically the list of properties produced in GI is seen as pre-existing the definition in that it is a selection from these properties that is used to produce the definitions.

Conclusion
Kuzniak and Rauscher (2005) comment on the same phenomenon and summarise it as follows: “So, the geometrical figure, totally determined by its definition, is confronted by a
drawing which in turn, is the basis for the definition” (p3). The work in this textbook chapter plunges learners into the heart of having to deal with this paradox. It requires sophistication in movement between geometric paradigms and tackling deep issues around the nature of mathematical activity. The textbook itself struggles with the movement and at points conflates the two paradigms. Clearly from textbook to teacher to learner a further translation of these ideas will take place. Although this study cannot make inferences about what will happen in the classroom, the analysis of the textbook highlights important tensions that need careful consideration.

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Dimensions of learning as identity: A demonstration from culturally-based lessons in grade 9 mathematics

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Abstract
This qualitative study examined the impact of culturally-relevant mathematics lessons on learners’ mathematical identity. Three Grade 9 mathematics teachers and their learners from one rural middle school in South Africa’s North West Province participated in the study. Through mathematising culturally-based activities, the research team indigenised (i.e. adapted to local culture) two Grade 9 mathematics topics. A teaching and learning unit on the indigenised topics was designed and implemented in five Grade 9 classes at the same school. In the discussion in this paper, we consider mathematics learning as a process of developing a mathematical identity. We address how Grade 9 learners’ practices in mathematics classroom communities shape learners’ perspectives of themselves. In this paper we view identity in two ways: how individuals know and name themselves, and how individuals are recognised and looked upon by others. We argue that culturally-relevant pedagogy can facilitate the development of learners’ mathematical identities by rationally using learners’ cultures to serve as a bridge between the learner and the subject. Learners’ mathematical identities were determined through analysing their narratives of mathematics classroom practice. We argue that the three interrelated dimensions: Competence, Performance and Recognition can be used to describe learning as identity. The paper analyses learners’ narratives of mathematics classroom practices in Grade 9 to demonstrate these dimensions of identity in the activity of mathematics learning.

Key words: Culturally-relevant pedagogy, identity, mathematics classroom community

Background to the study
The cultural placement of an educational system is probably the most relevant fact in modern development of education (D’Ambrosio, 1979). Many researchers have agreed that teaching must be related to its cultural and geographical context (Bishop, 1988; Kroma, 1996; Ascher, 1994; Gerdes, 1999; Mosimege, 2003; Madusise, 2010). There is consensus amongst these researchers that mathematics is being perceived as dry, uninteresting and irrelevant. Familiar subject matter and experiences that could be used to lay the foundations of the discipline, arouse learners’ interests and challenge their intellect early in life have been largely neglected (Kroma, 1996)

South Africa has embarked upon a curriculum that strives to enable all learners to achieve to their maximum potential (Revised National Curriculum Policy, 2002). Curriculum outcomes encourage learner-centred and activity-based approaches. Policy statements for Grades R-9 Mathematics envisage learners who will “be culturally and aesthetically sensitive across a range of social contexts” (Department of Education, 2002: 2). Interestingly, some assessment standards expect learners to be able to solve problems in contexts that may be used to build awareness of social, cultural and environmental issues. The National Curriculum Statement (NCS) challenges educators to find new and innovative ways to reach students from diverse
cultures in their mathematics classrooms. Valuing indigenous knowledge systems is one of the principles upon which the NCS is based.

Various theorists have outlined pedagogical strategies which incorporate students’ cultural backgrounds and prior experiences. Ladson-Billings (1994) asserts that culturally relevant teaching is designed not only to fit the school culture to the students’ culture but also to use students’ cultures as a basis for helping students understand themselves and conceptualise knowledge. Culturally relevant pedagogy has been defined as a means to use students’ cultures to bridge cultural knowledge and school knowledge (Boutte and Hill, 2006), to validate students’ life experiences by utilising their cultures, histories as teaching resources (Boyle-Baise, 2005), to recognize students’ home cultures, promote collaboration among peers, and connect home life with school experiences (Neuman, 1999). It would appear the proponents of this pedagogy generally contend that culturally responsive teaching acknowledges the legitimacy of the cultural heritages of different ethnic groups as legacies that affect students’ dispositions, attitudes and approaches to learning. Studies based on the concept of cultural differences make an assumption that students coming from culturally diverse backgrounds will achieve academic excellence if classroom instruction is conducted in a manner responsive to the students’ home culture (de Beer, 2010).

Many mathematicians, mathematics teachers and students possess “only a limited understanding of what and how [cultural] values are being transmitted” through the discipline (Bishop, 2001, p.234). Culturally relevant mathematics lessons work against this ignorance by reversing the trend in traditional mathematics curricula to divorce mathematics from its cultural roots (Troutman & McCoy, 2008).

Ladson-Billings (1995) documented the success of innovative lessons that appeal to diverse cultures in improving students’ attitudes towards classroom subject matter. Teachers who participated in her study developed lessons that incorporated the knowledge students gained from their lives outside of class and demonstrating the value of students’ home cultures and languages. By so doing the participating teachers positively influenced student test scores, engagement in the classroom community, and overall attitude towards school and learning (Ladson-Billings, 1995).

Lloyd (2001) conducted a five-year study aimed at showing teachers alternative classroom practices to better meet the needs of students. The study focussed on encouraging schools to promote the learning by all students through lessons that showed connections between mathematics and students’ lives. The most successful educators were those who fully embraced innovative and culturally relevant lessons. The study reported in this paper aimed to connect the teaching and learning of mathematics to cultural contexts, checking on the potential of culturally-based mathematics lessons for influencing learners’ mathematical identities.

**Theoretical framework: Identity development as a lens for mathematics learning**

Many researchers and theorists have considered how mathematics is learned, each foregrounding different aspects of the learning processes and viewing it from a range of theoretical frameworks. Learning mathematics can be viewed as building skills, using algorithms and following certain procedures. Another view focuses on students’ construction or acquisition of mathematical concepts (Anderson, 2007). This study focuses on the view that learning mathematics in schools involves becoming a ‘certain type’ of person with respect to the practices of a community. In this view, learning occurs through “social participation” (Wenger, 1998, p.4): learning “changes who we are by changing our ability to
participate, to belong and to negotiate meaning” (Wenger, 1998, p.226). According to Wenger all learning eventually gains significance in the kind of person we become. This paper addresses how Grade 9 learners’ practices within mathematics classroom communities shape learners’ sense of themselves - their identities.

Learning transforms our identities: it transforms our ability to participate in the world by changing all at once who we are, our practices, our communities, learning is a matter of engagement: it depends on opportunities to contribute actively to the practices of communities that we value (Wenger, 1998, p. 227).

Therefore learning mathematics also involves the development of each learner’s identity as a member of the mathematics classroom community. In this paper we view identity as “how individuals know and name themselves and how an individual is recognised and looked upon by others” (Grootenboer et al, 2006, p.612). Identity refers to the way we define ourselves and how others define us (Sfard & Prusak, 2005; Wenger, 1998). Thus identity is socially constituted, that is, one is recognised by self and others as a kind of person because of the interactions one has with others.

Putman and Borko (2000) stated that, “how a person learns a particular set of knowledge and skills, and the situation in which a person learns becomes a fundamental part of what is learned” (p.4). With this in mind, the impact of culturally-based mathematics lessons was determined through analysing learners’ narratives. Identity was then seen as a set of reifying, significant and endorsable stories about a person (Sfard & Prusak, 2005). Learning events and forms of participation are thus defined by the current engagement they afford. Problems of disengagement and non-participation in mathematics have tenaciously persisted for many years (Bishop, 2001). It is hoped that an investigation of mathematical learning as identity development through engaging in culturally relevant mathematics lessons may offer some new insights into how these issues can be ameliorated.

**A possible mathematics identity model**

In this section, we describe our mathematics identity model developed to provide analytical direction for our data analysis and interpretation. The model was adapted from Carlone and Johnson (2007)’s Initial Science Identity Model which is premised on both practical and theoretical sources of data. In our model a person who has a strong mathematics identity is described as someone who is competent; who demonstrates meaningful knowledge and understanding of mathematics content, who can perform for others her competences with mathematical practices/activities, and finally, someone who can recognise herself / himself, and gets recognised by others as a mathematics learner. These aspects of mathematics identity are captured in the following interrelated dimensions: competence, performance and recognition.

Any one of the three dimensions illustrated in the diagram in Figure 1 can be used to describe mathematical identity. However the intersection of either two or all the three sets can represent an even stronger mathematical identity.

**Research question**

This paper addresses the following central research question: What is the potential of culturally-based lessons in Grade 9 mathematics for influencing learners’ mathematical identities?
Methodology

To address the above question, data sources included learners’ pre and post questionnaire, teacher and learners’ interview transcripts, learners’ lesson journals, lesson observations, teachers’ reflective forms and transcripts from reflective meetings. These multiple data sources (Merriam, 1998; Yin, 2003) served as corroborating evidence to enrich the picture of teaching practices presented in the study and the stories learners tell about their engagement in the mathematics learning communities. The multiple sources of data provided convergent lines of evidence to enhance credibility of assertions (Yin, 2003).

Quotations from learners’ questionnaire responses and interview transcripts were used as narrative stories told by learners evaluating their participation. Excerpts from teachers’ interview transcripts and reflective meetings were used to find out how teachers recognised learners as a part of the mathematics learning community (Boaler, 2000; Wenger, 1998). Therefore the excerpts were used to determine learners’ mathematical identity, using the identity-as-narrative construct (Sfard & Prusak, 2005). Sfard and Prusak clarify that the identity-as-narrative construct assumes identity to be “human-made” rather than “God-given” (p.17). They assert that narrative is not a window onto identity, rather narrative is identity (p.14). Thus they suggest, identity is a discursive construct where identities are considered as “discursive counterparts to lived experiences” (p.17) limiting their definition to linguistic signs that index or represent a person’s lived experience. In agreement with this definition we used linguistic data from learners’ experiences to count as admissible evidence in constructing an account of identity.

In our model we considered identity as one of those self-evident notions that, whether reflectively or instinctively, arise from one’s first-hand experience. This is linked to the work of Lave and Wenger. According to Lave and Wenger (1991, p. 53) “learning… implies
becoming a different person... learning involves the construction of identity”. Therefore, “being a kind of person” remains the centrepiece of the definition of identity. The motif of a “person’s own narrativization” recurs in the description proposed by Holland et al. (1998):

People tell others who they are, but even more importantly, they tell themselves and they try to act as though they are who they say they are. These self-understandings, especially those with strong emotional resonance for teller, are what we refer to as identities (p.3).

Samples and sampling procedures

The sample in this study consisted of three mathematics teachers from one middle rural school in the North West Province of South Africa and their Grade 9 learners. Purposive and convenience sampling was used to select the research sites (Patton, 1990). Merriam (2009) identifies purposive sampling as one appropriate sampling strategy in case-study design. Merriam (2009) further adds that purposeful sampling is based on the assumption that one wants to discover, understand, gain sight; therefore one needs to select a sample from which one can learn the most. In this case, a cultural village was identified as the research site and mathematics teachers who teach at a school very close to the selected cultural village were focused on. A cultural village was selected with the belief that it is where the community’s indigenous knowledge is preserved. The intention was to make the cultural village a mathematics teaching resource centre. A school close to the cultural village was chosen with an assumption that its members (including learners) are quite familiar with the activities taking place at the cultural village.

Grade 9 was chosen based on the argument that it is a transitional grade from GET to FET where students after Grade 9 are to choose between Mathematics and Mathematical Literacy. At Grade 9 students are learning mathematics which combines aspects of both Mathematics and Mathematical Literacy. At Grade 9 learners have more experience with mathematics than learners at earlier grades. Doing the study at FET level would have limited the number of participating learners as some learners might have perceived it as being linked to Mathematical Literacy and would therefore withdraw since everyday examples are usually associated with Mathematical Literacy.

1 A cultural village is a tourist establishment where tourists can view aspects such as the homestead, traditional clothing, food and food-related practices, history and societal structures as well as song and dance routines of one or more of South Africa’s cultures (Mearns & du Toit, 2008).

Setswana step dance, a cultural dance practised at a cultural village near the school, was used as a context for teaching number patterns. A group of Grade 9 learners demonstrated the dance and a number pattern was observed involving the number of dancers and the number of foot-steps (see table below). The second row shows the total number of steps made by all the dancers if each dancer is making five steps.

<table>
<thead>
<tr>
<th>Number of dancers</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>-</th>
<th>-</th>
<th>-</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of foot-steps</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>nx5</td>
</tr>
</tbody>
</table>

Some tasks were formulated using the artefacts from the cultural village. Step dancing was again used to teach substitution using number of dancers as input and number of steps as

5 These learners had previously participated in cultural dances at the Cultural Village near the school.
output. In another topic, artefacts from the Ndebele paintings and beadings, (see Figure 2 below) were used to teach properties of shapes and transformations.

![Ndebele beadings](image)

**Figure 2:** Ndebele beadings

Three lessons were taught in each of the three classes (two for Teacher A and one for Teacher C). All the 9 lessons were taught by the researcher, while the class teachers were taking videos. Four lessons were taught in each of Teacher B’s two classes. Three of these lessons in each of Teacher B’s classes were taught by the researcher and one in each class by the class teacher (Teacher B). Altogether 17 lessons were taught and video recorded. Reflective meetings were held after every lesson. Lessons were collaboratively planned by the researcher and the class teachers.

**Nature of data and data analysis**

The data collected in the study on which this paper is premised included seventeen video-recorded culturally-based lessons from five Grade 9 classes, learners’ responses from pre and post questionnaires, learners’ lesson journal entries, audio-recordings from learners’ group post-lesson interviews, audio-recordings of teachers’ pre and post interviews, notes from post-lesson reflective meetings with teachers and teachers’ lesson reflective forms. In this paper we focused on learners’ narrative stories, on their perspectives of culturally-based lessons, triangulating data from lesson journal entries, post-lesson questionnaire responses and post-lesson interview transcripts. We also used teachers’ narratives from the post-lesson reflective meetings and the post-interview transcripts to check on how they recognised learners’ capabilities as mathematics learners.

Learners were asked to complete journal entries after every lesson, to reflect on their learning. Questions for the post-lesson questionnaire were constructed to check on learners’ views about the importance of learning mathematics and their perspectives on how the incorporation of culturally-based activities in mathematics lessons impacted on their mathematics learning. Interviews were carried out to probe learners’ responses from journal entries and post-lesson questionnaires as well as checking on learners’ perceived learning trajectories. In analysing the data, the narratives were accordingly coded using the themes; competence, performance and recognition – the dimensions of identity (see Figure 1). The approach to analysis involved identifying the “words” learners used to represent their experiences and how social relationships and practices produced confidence and pride in the learning. When analysing learners’ responses, expressions like: I feel good, happy, excited,
educated, impressed, cool, amazed etc., were categorised as indicating learner satisfaction. Narratives depicting the same theme were grouped together into a vignette and commented on in detail.

Data presentation and discussion
To begin the analysis, completed questionnaires were given identity codes that represent the type of questionnaire, the class of the learner and the number of the questionnaire. This was also applied to the learners’ journals. For example a questionnaire completed by a learner in Grade 9A was identified as Q1LA01, Q1 denoting first questionnaire and Q2 denoting the final questionnaire, LA denoting learner from Grade 9A, and 01 denoting the number of the questionnaire. For J1LA01, J1; J2; and J3 denote Lesson Journal 1, 2 and 3 respectively and LA01 with the same representation as above. For GILA01, GI denote group interview.

In the following sections, vignettes are presented and commented on to identify and demonstrate aspects of learning as identity.

Vignette 1: Factors which contribute to the difficulty of mathematics
This vignette contains extracts from learners’ responses on the question: What factors do you think may contribute to the difficulty of mathematics? Please explain. This question was designed to understand learners’ participation as well as non-participation and of inclusion as well as exclusion in the mathematics classroom community. Learners were asked to answer the above question prior the intervention teaching.

Q1LA02: In mathematics you work with numbers when in other subjects you work with words, there are no notes or scenarios
Q1LA08: Equations are difficult, you need to do all your steps correctly. If you miss some steps you get wrong answer.
Q1B39: The way teachers teach. Other teachers explain very fast, others do not know how to teach and they say we do not know mathematics.
Q1LC14: The difficult of mathematics is to work with algebra and equations. Things we do not understand give us stress or headache.
Q1LD24: The difficult factors for me are when you do things which you do not talk about every day e.g. prime factors because we do not talk about them every day.
Q1LD06: Mathematics needs more time than other subjects.
Q1LD41: Strict teachers contribute a lot to the difficult of mathematics because sometimes you are afraid of them especially when you do not get the required answer.
Q1LE08: The difficult of mathematics is that you cannot calculate the answer without following some steps. I just do not like going through each and every step without my own shortcuts.
Q1LE27: Unlike other subjects, it is difficult to read mathematics.

Comment
Learners’ comments on the question were divided into seven categories as follows: teaching and learning styles, nature of mathematics, insufficient resources, anxiety, procedures, language barrier, and insufficient time. However, the way teachers teach was cited as the major contributing factor to the difficulty of mathematics. Eighty-one (81) out of 157 (52%) learners cited factors related to this category. Reasons like missing notes and scenarios (See Q1LA02; Q1LD24) were given. In the vignette above, Q1LA02 expressed dislike of learning mathematics without using related scenarios and Q1LD24 emphasised that lack of connections to everyday life makes mathematics difficult. Learners who do not have the opportunity to connect with mathematics at a personal level may fail to see themselves as competent at learning mathematics (Boaler & Greeno, 2000). According to Q1LB39, the treatments they get from their teachers contribute to their non-participation in the mathematics lessons. Learners who do not see themselves or are not recognised as contributors to the mathematics classroom may not consider themselves to be capable mathematics learners.

One way learners come to learn who they are relative to mathematics is through their engagement in the activities of the mathematics classroom. This idea of following laid down procedures without own creativity does not go down well with some learners (Q1LE08). When learners are able to develop their own strategies and meanings for solving mathematics problems, rather than following laid down procedures, they learn to view themselves as capable members of a community engaged in mathematics learning (Boaler & Greeno, 2000). Therefore, the types of mathematical tasks and teaching and learning structures used in the classroom contribute significantly to the learners’ mathematical identities.

The nature of mathematics as a contributing factor to the difficulty of mathematics was cited by 40 learners (~25%). Comments like, it is difficult to read mathematics (Q1LE27), in mathematics you work with numbers when in other subjects you work with words (Q1LA02), in mathematics there are some required answers (Q1LD41) were emphasised. Learners who are not the quickest to get the required answers may see themselves as not capable of learning mathematics. Insufficient time (Q1LD06) and lack of resources like calculators was also emphasised as contributing to the difficulty of mathematics. For these learners the availability of learning resources is an important prerequisite for mathematics learning. The use of English language in mathematics was also cited as another contributing factor to the difficulty of mathematics since mathematics is a language which is being taught in their second language (English). Therefore, learners are struggling to understand these two languages simultaneously. Learners with problems in English language may not see themselves as capable mathematics learners.

The above vignette highlights that, before the intervention, lack of good teaching strategies, good treatment by teachers, and connections to everyday life may have contributed to learners’ weak mathematical identities (low capability of doing mathematics). Use of procedures and the nature of mathematics may also contribute to a weak mathematical identity.

Vignette 2: Competence as an identity dimension
In this vignette the following narratives have been cited to show learners’ comments on their acquisition of mathematical knowledge and understanding of the mathematics content learnt after participating in culturally-based lessons.
Q2LA05: I feel very amazed because I can see that other cultures they do mathematics in their own way which makes it easy to know number patterns and transformations.

Q2LA28: I like the fact that I understand the whole topic (referring to number patterns), so I am excited when I get questions based on the topic. I am proud of my work.

J1LA21: Today I have learnt the following things in the number patterns; forming a number pattern from the Tswana dance, getting the position of the term in the number pattern, getting the general term and the rule connecting the terms.

Q2LB02: I feel that number patterns are simple when we use the Setswana dance or any other dance from our culture. Because we listen and look, count their steps when they are dancing and get some mathematics.

Q2LC02: I like using our culture because it made me understand maths.

Q2LD26: I feel very impressed because I did not know number patterns but I now know them very well and I hope they can put them in the examinations.

Q2LC09: I feel like I can now handle anything in mathematics, mathematics is not all that difficult.

Q2LE06: I liked these two topics because there is something in my mind now that I have learnt about – it reminds me that in the olden years in my culture, our elders used powerful mathematics also.

Comment

The above quotations from learners overwhelmingly point to the success of learners in their engagement and understanding the concepts that were part of the culturally-based lessons. Out of 169 learners who responded to the questionnaire, 163 (96%) expressed satisfaction and 44% of the learners felt satisfied with the way they learnt the two indigenised topics because they gained a good understanding in these topics. Some learners (e.g. Q2LD26) even wish to see questions on the covered work in the examinations. This indicates a very high degree of competence and confidence. This is further epitomised by Q2LC09 who feels competent to “...handle anything in mathematics...” Q2LA28’s competence is indicated by his/her sentiments that s/he understands the whole topic (number patterns), excited to get questions based on the topic and proud of her/his work. Most learners expressed more or less explicitly their pleasure to learn mathematics and a satisfaction in completing a task. In the lesson journals almost every learner was able to express explicitly what s/he learnt during the intervention lessons (JILA21). This fluency in mathematics talk demonstrates meaningful knowledge and understanding of the experienced mathematical content.

Some of the learners in the study experienced the “aha” moments and joy of mathematical discovery, discovering a link between mathematics in the classroom and the mathematics used in the cultural activities. Their expressions (Q2LA05) revealed surprise in this gain of knowledge. Grootenboer and Zevenbergen (2007) asserted that such personal responses, describing mathematics in terms of “wonder”, “beauty” and “delight” provide motivation in terms of continued engagement and fuel a passion for the discipline of mathematics. On the other hand, statements like those expressed by Q2LA05 and Q2LB02 suggest that, for them, the culturally relevant lessons did address Ladson-Billings’ (1995, p. 160) requirements for this kind of teaching where learners are expected to “experience academic success, develop
and/or maintain cultural competence”. Interestingly, knowing that even their fore fathers were also doing what they termed powerful mathematics (Q2LE06) may spur them to acquire a strong mathematical identity. Their admission that they did not know the possibility that some mathematical concepts might have evolved in their cultures, not knowing that people in their cultures were also doing mathematics in their cultural activities, prior to the lessons, suggests that the lessons encouraged the development of their “cultural competence” as mathematics learners.

However, six out of 169 learners who responded to the post-lesson questionnaire expressed that they were unsatisfied with the way they learnt the indigenised topics. Such learners had this to say:

Q2LA32: I was feeling so boring because I do not love mathematics.
Q2LB29: I feel nothing because I don’t like mathematics.

For these learners, any innovative method introduced may not have had a positive impact on them because they do not like mathematics. They attend mathematics lessons because mathematics is a compulsory subject. Given a choice they would drop the subject.

Vignette 3: Performance as an identity dimension
Below are some narratives from learners which indicate how they valued their social performances in the culturally-based lessons which were referred to as participation in a project during group interviews.

JILD01: I liked sharing my ideas with my teachers and other learners.
J3LE12: I really liked the introduction using cultural songs and dance.
Q2LE17: It was interesting. I was learning something now.
Q2LE29: I learnt number patterns by the things that I could understand and doing number patterns is very easy, you can even do them without using a calculator.
Q2LE04: It was very, very interesting because I was watching the Ndebele drawings, they used transformations and they are good.
Q2LE03: I feel very good when they teach a lesson showing me how it works.

R: Do you think the way you are thinking about mathematics now is different from the way you were thinking about mathematics before the project?
G1LE03: Yes! Mathematics, I thought was very tough. But now because the project I just see it as a subject which everyone is doing even outside school.

R: Do you think that the way you have been asking questions about mathematics before the project is different from the way you can ask questions now?
GILE03: It has changed. Before I used to think of questions like … Does this work? How does transformation work? Where do we use transformations and so forth… Yeah, but now I won’t think or ask myself such questions. I will start thinking or looking for places where such things can be applied in our cultures. Yeah I now know our cultures use such mathematics.
Comment

Although using the identity-as-narrative construct may sound valid, when it comes to performance, there is a need for triangulation. Because of this need, learners’ narratives were cross-checked against observation data, i.e. checking how learners participated in the culturally-based lessons. Lesson videos were replayed. This then entailed rigorous validation of data procedures.

Learners valued sharing of ideas with their teachers and classmates (J1LD01). Being part of a group and working as collective enabled learners to share their indigenous mathematical knowledge. This sharing of knowledge stated in the narratives was observed during lessons when discussing cultural incidences where number patterns can be observed (Venda clothes, Zulu baskets and different cultural dances). The mathematics classroom can also be organised to encourage discussion, sharing and collaboration (Boaler, 2000). Group activities were satisfactorily and actively done. The fact that the learners liked the sharing of ideas, this active participation included not only thoughts and actions but also membership within a mathematics classroom community. Learning mathematics involves the development of each learner’s identity as a member of the classroom community (Wenger, 1998). Learners were observed being central to the community of practice. Through the observed warm relationships and valued experiences with their peers and teachers, it can be concluded that these learners came to know who they are relative to mathematics. Due to the non-threatening and supportive environment, learners could actively engage in the activities at levels that met their understanding. This ethos has been documented in Boaler’s studies (Boaler, 2002a, 2002b) as being one that enables learners to participate without threat and hence open up opportunities for participation and learning.

Learners also valued the unique experiences of using cultural contexts in teaching and learning (J3LE12; Q2LE04). These experiences were unique in the sense that mathematical knowledge was constructed out of culturally-based activities. “I know how to dance and I now know how to draw a number pattern from a dancing style” (J1LD02). This contention shows the learner’s capability to construct mathematical knowledge from a culturally-based activity—a dance, sending a message that culturally relevant pedagogy can provide a worthwhile learning experience (see Q2LE17; Q2LE29). The idea of involving learners in practical activities was positively received by learners (Q2LE03) who seem to like the visualisation involved. The same statement by Q2LE03 was observed by Teacher A during lessons and reiterated in the last interview: “Personally I have realised learners understand more easily when the lesson is practical. Yeah... when learners are involved in a lesson they participate with interest” [emphasis placed] (TR A, Final interview, 16/03/2012). The practical work provided a range of affordances and issues related to mathematics and mathematics learning—learners’ mathematical identity. Some learners are now thinking of searching for mathematical knowledge from cultural activities (GILE03). Therefore identities get formed in practice (Lave & Wenger, 1991).

Vignette 4: Recognition as an identity dimension

Self-recognition

GILE03: I see myself as a whiz-kid in mathematics (Group-interview, 05/03/2012)

GILE01: I see myself as a whiz-kid too because I can now understand mathematics.

GILE02: Me, I can see myself as a champion because I understand everything we learnt in the project.
GILB02: Mathematics is now simple to me.
GILB01: I can now understand mathematics better when mathematics examples from our South African cultures are used.
GILB03: I think much has changed because I used to see cultural activities as activities which just ended at the village but now … now I can use the activities to understand the mathematics we learn at school, to simplify my work.
GILE02: Yes, before the project I used to consider mathematics as tough. Even when we were given some work to write, I used not to write, but now I am so happy. I did not like mathematics; I hated it so much but now …
GILB04: In future we will try to use the same method we used in the project to learn mathematics, thinking about how the same mathematics is being used in our cultures.

Comment
Most learners in the study described themselves as capable mathematics learners; they began to imagine themselves as fitting into this community of practice. Imagination involves “the creative process of producing new ‘images’ and of generating new relations through time and space that become constitutive of self” (Wenger, 1998, p. 177). One hundred and sixty-four out of 171 (95%) learners positively acknowledged culturally relevant pedagogy as enabling them to understand mathematical topics taught in the lessons better. Some learners emphasised that their engagement in culturally relevant lessons will significantly influence their future mathematics learning (GILE02; GILB04). However, this may depend on the nature of the mathematical concepts, providing possible connections to cultural knowledge. Culturally relevant lessons also afforded learners with the opportunity to see themselves as mathematics learners even when they are away from the classroom (GILB03). Learning is being viewed as a trajectory. As trajectories, our identities incorporate the past and the future in the very process of negotiating the present. “Community of practice is a living context that can give newcomers access to competence and also invites personal experience of engagement by which to incorporate that competence into an identity of participation” (Wenger, 1998, p.214).

Recognition by others

TR B: The funny thing is that the learners were able to make their own explanations from what they saw, they could visualise everything and could deduct their explanation from that. (Final interview, 15/03/2012)

TR A: Learners were involved because they actively participated in the discussions and at least they understood the lessons easily. (Final interview, 16/03/2012)

TR A: I realised that practically, it is the way to go and learners can do better when their cultures are involved. (Final interview, 16/03/2012)

TR B: In my lessons only three or four learners participate, but in these lessons almost all learners participate. In groups I could see they were sharing ideas. I also observed that almost all the learners submitted the given tasks unlike in my previous lessons. Most learners do not write home work. (Notes of reflective meetings, 21/2/2012)
Comment
This recognition of learners by their teachers, as becoming capable mathematics learners due to their engagement in the culturally relevant lessons happened repeatedly especially when reflecting on the lessons. According to the observation by TR B, learners were involved in mathematical thinking because they could come up with their own explanations. Learners also made an effort to complete and submit given tasks. Shannon, (2007) posits that a realistic context will facilitate student success by intrinsically motivating students and thus increasing the likelihood that they will make a serious effort to complete given problems. This is another indication of successful participation in the mathematics classroom community. All learners can become mathematics learners, identifying themselves and being recognised by others as capable of doing mathematics (Anderson, 2007, p.13).

Learning from learners’ narrative stories
The majority of the learners in the study expressed their experiences in culturally-based lessons in terms of competence, performances and recognition. Their engagement in the lessons led to the definitions of their actions as competent members of the mathematics classroom community. Contrary to their initial thinking that the way teachers teach contribute to their non-participation in the mathematics classroom community, learners perceived culturally relevant pedagogy as an enabling pedagogy which can provide access to mathematics. They valued their experiences in the culturally-relevant lessons as unique, where mathematical “knowledge was pulled out” of culturally-based activities (Ladson-Billings, 1995, p.479) and the construction of knowledge was part of the learning experiences. They recognised themselves and were recognised by their teachers as now capable mathematics learners. What then can we learn from their stories?

The dimensions of identity reflected in this paper can be used to understand how learners label themselves as members of the mathematics community in relation to teaching and learning strategies. Thus these findings interrogate a strategy for drawing learners into mathematics, stimulating their interests, enthusiasm, competence and confidence. Learners’ experiences may not necessarily reflect only one of the three dimensions of identity described in this paper. All the three or two dimensions can be intersected, therefore leading to an even stronger mathematical identity. One learner can label himself/herself as good in mathematics due to the experienced competence through participating in some unique experiences. Teachers can provide learners with opportunities to see themselves as mathematics learners away from the classroom (Anderson, 2007). The various images learners have for themselves and of mathematics extending outside the classroom - in the past, present, or future may change over time (learning trajectories) and this change may be influenced by the espoused pedagogies.

Conclusion
Through consistent and sustained efforts by mathematics teachers to develop positive identities in their learners, we argue that more learners can improve their identities as mathematics learners. As pointed throughout this paper, identities are socially developed in relationships with others, including teachers and peers in the learning community. We designed a mathematics identity model which enabled us to look at what happened within culturally relevant mathematics lessons. This model highlighted competence, performance and recognition as interrelated dimensions for describing learning as an identity (Wenger,
The use of culturally relevant pedagogy positively impacted on learners’ mathematical identities since the learning trajectories reflected in the learners’ narratives show that learners were drawn more centrally into their community of practice, recognising themselves as competent mathematics learners basing on the two topics taught in the study and their perceived future anticipations.

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The intended and the implemented: one task in a GeoGebra context

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Abstract
There is often a misalignment between the intended pedagogical purpose of a task and its implementation by learners. This may be exacerbated when the mathematical task exploits the affordances of technology. In this paper I use a dedicated framework to isolate, a priori, the possibilities and limitations of a specific GeoGebra-based mathematical task and to compare this with the actual realizations of this task by a group of students. These students were participating in a post-graduate university course for in-service mathematics high school teachers in South Africa. The analysis demonstrates that although a specific computer-based task may have one pedagogic purpose and appropriate mathematical and technical demands, different students may require different levels of scaffolding to complete the task. As a result, they may engage in the task at various levels of cognitive demand.

Rationale
Tools such as the abacus and the slide rule have long been used in the learning and teaching of mathematics. Today many mathematics educators (Heid & Blume, 2008; Hitt & Kieran, 2009; Pierce & Stacey, 2010, and so on) advocate the thoughtful use of tools such as computers for the learning and teaching of mathematics. Indeed it is generally acknowledged that the use of such tools may assist mathematical understanding (Zbiek & Hollebrands, 2008) and may promote deeper understanding of advanced mathematical concepts (National Council of Teachers of Mathematics, 2000). In Vygotskian terms, various computer software programs may be seen as tools of semiotic mediation in the zone of proximal development (zpd) of different learners. The type and quality of mediation that the computer affords depends on very many different factors, ranging from the sort of activities or tasks which students are expected to engage in, while using the tool, to the technical expertise of the actual students and their ability to exploit the technical features of the technology. The latter technical expertise may have a direct affect on the mediating role of the tool for the different learners.

What do we mean by a ‘task’? Mason and Johnston–Wilder (2006, p. 22) contend that “the purpose of a [mathematical] task is to initiate mathematically fruitful activity that leads to a transformation in what learners are sensitised to notice and competent to carry out”. In line with this I use the term ‘mathematical task’ to refer to an assignment that is purposefully designed or selected to focus the learner’s attention on some mathematical concept and/or process. A ‘computer-based mathematics task’ is a mathematics task which allows the use of a computer for its execution; pencil and paper may also be used in such a task.

In this regard, computer-based tasks may provide opportunities for learning which may not be available in the paper and pencil world. At the same time, these opportunities may be diminished if the design or structure of the task is not appropriate. For example, the intended focus of a particular mathematical task may be lost if the technical demands of using the computer software are too high. On this point, the use of certain computer algebra systems (CAS) often requires knowledge of specialized syntax, and learning to use this syntax may shift the students’ attention away from the mathematical focus of the task. Also interpretation
of the computer output, which may differ in form from that of pencil and paper mathematics, may be difficult and this may lessen the intended pedagogical value of the task.

Given the relative lack of experience of many mathematics teachers with computer-based tasks, a framework within which teachers and researchers can analyse the structure and purpose of these multi-faceted tasks both before and after implementation, is desirable. Berger (2011) developed a framework for an a priori analysis of computer-based tasks. She claimed (although she did not demonstrate) that this framework could also be used, a posteriori, to isolate the extent to which these pedagogical intentions are realized in the actual execution of the task by the student. Such an analysis would illuminate the relationship between the intended pedagogical purpose of the task, its structure, and its actual execution.

In this chapter, I use this framework to analyse, a priori, the features and pedagogical purpose of a computer-based task; I compare this analysis with an a posteriori analysis in which the execution of the task by a group of thirteen students is examined. This comparison illustrates how one task may assume many different forms when implemented by different students. The implications (for mathematics learning) of the differing realizations and hence, pedagogical value of one task to several different students in one classroom are immense. I do not pretend to examine these implications here; rather I signal their existence and hope that this may lead to further interrogation of this reality.

**Research questions**

How does the pedagogic purpose of a computer-based mathematical task get transformed in its execution?
In particular, how do its intended mathematical focus, its intended cognitive demand and its expected level of technical difficulty get transformed in execution?

**The framework**

Below I offer a summary of the four primary components of Berger’s (2011) framework. For further details and motivations for these different components see Berger (2011).

**Mathematical focus**

In line with Mason and Johnston–Wilder’s (2006, p. 22) definition of a task (see above), a task is expected to focus the learner’s attention on a specific mathematical concept and/or process. Through this focused activity, the learner is expected to make sense of the particular mathematical notion. Accordingly, the category ‘mathematical focus’ is a key feature of the framework.

**Cognitive demand**

Following Stein, Smith, Henningsen & Silver (2009), the most important characteristic of a mathematical task is its cognitive demand, that is, the “kind and level of thinking required of students to successfully engage with and solve the task” (p. 1). Different mathematical tasks offer different opportunities for the type or level of learning. According to Stein et al (2009), some mathematical tasks are designed to reinforce memorization of mathematical facts; they involve reproduction of previously learnt formulae or definitions (memorization tasks). Other tasks focus on procedural know-how and may require the selection and execution of an appropriate algorithm (procedures without connections); other tasks are designed so that the learner engages with properties of a mathematical object and their links to other mathematical objects (procedures with connections); yet other tasks are designed to develop reasoning,
justification skills and communication (doing mathematics). Since different activities are expected in each of these types of tasks, different sorts of learning are expected to take place. In the context of a computer-based task, the types of tasks which promote these cognitive demands are necessarily different to traditional tasks. Below I elaborate each of these types of tasks in the technological environment.

Since many mathematical facts are reified in the software, **memorization tasks** within a technological environment often involve the verification of a particular fact or formula (for example, \( \sin^2 x + \cos^2 x = 1 \), sum of angles in a triangle is 180°). In a dynamic geometry system (DGS) context ‘memorisation’ tasks are often the starting point for other sorts of tasks (which may extend the cognitive demand of the task). For example, to define a rectangle in a dynamic geometry environment, the user needs to know/memorise the defining properties of a rectangle.

Since programmable calculators and computers can easily execute algorithms, ‘**procedures without connections**’ tasks in a computer context focus on the selection of an appropriate algorithm by the learner (to be executed by the software) and the interpretation of its output. Such tasks, which outsource computations to the computer, may allow the user to focus on more conceptual aspects of the task. Under certain circumstances the relative ease with which the user may use the computer to execute procedures may support pencil and paper algorithmic skills. For example, Kieran and Damboise (2007) demonstrated how the use of CAS to generate factorisations and expansions of expressions scaffolded the learning of weak Grade 10 learners. Being able to examine the patterns of the computer-generated factorisations and expansions and knowing that they were correct, supported the development of these learners’ paper and pencil skills.

‘**Procedures with connections**’ tasks focus on the use of procedures for the purpose of developing deeper levels of mathematical understandings of specific concepts. These tasks usually suggest general procedures which illuminate the underlying concepts and they often involve making connections across multiple perspectives. The availability of technological tools lends itself to the design or selection of such tasks. For example, see task below.

‘**Doing mathematics**’ tasks require non-procedural and complex thinking. The learner has to determine her own path through and approach to the problem. Such tasks require the learner to analyse the task; successful execution of the task involves the learner exploring and using various mathematical concepts, processes or relationships. As with ‘procedures with connections’ tasks, many opportunities for the design or selection of ‘doing mathematics’ tasks are provided when the use of computers are permitted. Again, see task below.

**Use of technological affordances**

Different tools have different affordances for the learning and teaching of mathematics. However there are some affordances that are common to many technological tools such as CAS. Probably one of the most important of these (demonstrated in the task below) is the capacity of the software to represent one mathematical object with different representations i.e. symbolic, graphical, numerical representations. Indeed many mathematics educators have argued that the ability of the user to use the technology to move between different representations of mathematical objects promotes conceptual growth (for example, Heid & Blume, 2008; Tall, 2008). Alternatively the use of different sign systems (algebraic, graphical, numerical, verbal) to represent one mathematical object, may allow the user to see the same mathematical object in different ways, thus illuminating which properties of the object are invariant, which are not.
In the task below, we see another very important attribute of CAS: outsourcing computations. That is, the use of CAS may eliminate the need for by-hand cumbersome symbol manipulations so freeing students to concentrate on the formulation of solutions (Heid, 1988). Similarly, graphing software may be used to generate graphs of functions which may be tedious to do by hand. The outsourcing of awkward computations to the computer may allow the user to engage in conceptual thinking even if she has poor manipulation or procedural skills. Dunham and Hennessey (2008) argue that this affordance may be one of the strongest arguments for using technology to achieve equity for low-achieving disadvantaged groups of students. Related to this liberating role of CAS, is Dörfler’s (1993) suggestion that the separation of the execution of mathematical tasks (performed by the computer) from the planning of mathematical tasks (carried out by the learner) could result in an increased focus on conceptual planning and problem-solving.

Another important affordance of certain technologies like CAS and DGS is the use of dynamic representations. Dynamic representations are utilized in tasks which explore how the properties of a particular function (for example a trigonometric function) may change as the values of various parameters change. As with multiple representations of a single object, this may give insight into invariant or variant properties of families of functions. In the context of dynamic geometry systems, the user may ‘drag’ an element (e.g. a line segment or a point) of a previously-defined geometrical object, such as a rhombus, to see which features of the object are invariant. In contrast to this dynamic representation of mathematical objects is the capacity of CAS to reify certain processes into objects. This potentially affords a new way of working with mathematical processes (for example, one can use CAS to manipulate a function as if it were an object). Related to this, Heid and Blume (2008) highlight how users may employ technology to work with families of functions and how technology can transform the mathematical object, function, into a ‘manipulable’ object.

The use of CAS to verify by hand solutions (such as algebraic computations or sketches of particular functions) may give the student confidence in their solution or the confidence to proceed with the task. Thus the possible affordances of the use of the computer may extend to the affective domain.

Although there are many other possible affordances of CAS and DGS, the discussion above should suffice to demonstrate the different ways in which different tasks may exploit different aspects of the CAS or DGS so serving a particular mediating role in the learning activities of the students.

**Technical demands**

Although the mathematical content of a computer-based task may be appropriate for the learners, the technical demands implicit in the task may move the task beyond the zone of proximal development for some of the learners. Thus a mathematical task which may focus on appropriate and appealing mathematics content may require such complex technological skills that it has very little, if any, value in a particular mathematics classroom. This may be particularly relevant in a context in which many of the learners are digital immigrants. (A digital immigrant’ is someone who was born before the widespread existence of digital technology (Prensky, 2001)). For example, see Berger (2010) where the syntactical difficulties that first-year undergraduate mathematics students had in the Mathematica environment when they needed to solve an equation involving a transcendental function and a polynomial are highlighted. In developing countries such as South Africa, there is a further concern that the use of technology in the learning of mathematics may exacerbate disparities.
between students with different socio-economic backgrounds. Care needs to taken so that the use of technology does not alienate those students with less material access to and experience with technology.

**Implementation of the task**

**Intended and implemented task**

There is often a disparity between the intended cognitive demands of a task and its implementation by learners (Stein, Grover, & Henningsen, 1996). In this regard Stein et al. (1996) show how the cognitive demands of (non computer-based) tasks in reform-orientated classrooms significantly decline as a result of particular interventions (such as too much assistance) by the teacher. In this paper, I compare a lecturer’s pedagogic expectations of a computer-based task with its actual implementation in a university classroom. I try to isolate those features of the implementation of the task which may result in reduced cognitive demand.

**The course**

The task presented below derives from a course on functions given to in-service high school teachers in South Africa. The purpose of the course was to revisit an old topic – functions – from different perspectives. For reasons born out of South Africa history, many of the mathematics teachers in SA have a degree or diploma in Education rather than in mathematics. Most of the teachers in our course came from this group. These teachers’ content knowledge is fairly weak and so our aim in this course was to revisit functions, extending and deepening teachers’ knowledge of this basic concept. The course was structured as a part-reading, part-activity course. The class met once a week for a three hour session. Students were expected to study (this included doing examples) a specific chapter from the prescribed mathematics textbook, Precalculus (Sullivan, 2008) prior to their weekly session. Since several of the teachers did not have access to a computer at home, examples which required the use of technology were not prescribed for home activity. During the three-hour session, the class discussed the topic they had studied at home for the first hour. They were then presented with tasks around the topic which they did on their own or in pairs. Some of tasks required the use of technology (in this case, GeoGebra), others did not. Many of the in-service teachers were newly arrived digital immigrants and so it was very important that the technical demands of the task were appropriate. Most tasks were designed, selected or adapted by one of the lecturers, Lynn Bowie.

**Task**

The task examined in this paper, was one of several tasks done in a session in the middle week of the course.

Use GeoGebra to find an approximate value of \( f^{-1}(20) \) where \( f(x) = x^3 + x + 1 \). Note: GeoGebra does not have a quick way of producing the graph of \( f^{-1} \). You can answer this question without the graph of \( f^{-1} \).

Note: Prior to this task students were asked to use GeoGebra to decide if \( f(x) = x^3 + x + 1 \) has an inverse function or not. Having decided or assumed that it did, they could proceed with the above task.

It is also relevant to note that GeoGebra 3 was used for this task. (In GeoGebra 4, generating the inverse of a function is a trivial task.)
Intended execution of task: A priori analysis
In this task, students were expected to use GeoGebra to plot the graph of \( f(x) = x^3 + x + 1 \). Using this graph, they could find \( f^{-1}(20) \) by locating 20 on the \( y \)-axis and finding its corresponding \( x \)-value. They were expected to reason as follows:

Assume \( f \) has an inverse function \( f^{-1} \).

Suppose \( f^{-1}(20) = a \).

Then \( f(a) = 20 \).

Thus to find \( f^{-1}(20) \), locate 20 on the \( y \)-axis, and find the corresponding value of \( x \).

Given that this a non-standard task for which the learner needed to devise a non-standard approach, the task was classified, a priori, as requiring a cognitive level of ‘doing mathematics’.

In terms of technical demand the user needed to generate a graph of \( f(x) \) and then may have needed to change window size so that 20 was visible on the \( y \)-axis. They could then read the corresponding \( x \)-value by inspection or by using GeoGebra to find the intersection of \( y = 20 \) and a point on the graph of \( f \). Technically, this task requires standard but multiple steps.

As it is presented, the task requires students to focus on the relationship between domain and range of a function and domain and range of its inverse. This focus is not made explicit in the task nor is any pathway to the solution given. Thus the task is classified as having the cognitive demand of ‘doing mathematics’.

With respect to the exploitation of GeoGebra’s affordances, the task could hypothetically be done in a paper and pencil environment. But finding the \( x \)-value corresponding to \( y = 20 \) for \( f(x) = x^3 + x + 1 \) by trial and error, or through the accurate sketching of the non-familiar graph \( f \) would waste time and so detract from the thinking about the relationship of a function to its inverse. In this case adapting the task from a computer-based task to a pencil and paper task would essentially change the nature and focus of the task; accordingly the thinking skills and cognitive demands of the task would necessarily be changed.

The a priori analysis of the task in terms of the framework is summarised in Table 1.

Actual implementation of this task
Each student did this task on his/her own but they were free to discuss the task with each other or to ask the two lecturers in charge of the tutorial for assistance. Students were asked to hand in their answers to this and other tasks at the end of the session although they were not obliged to do so. In the event, 13 out of the 18 students handed in their written response to these tasks. One lecturer took field notes about students’ activities during the session.

Table 1: Summary of a priori analysis of Task 1

<table>
<thead>
<tr>
<th>Category</th>
<th>Mathematical focus</th>
<th>Technical demands</th>
<th>Cognitive demand</th>
<th>Use of technology’s affordances</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Relationship between domain and range of function and</td>
<td>Straightforward; multiple steps.</td>
<td>Doing mathematics.</td>
<td>Outsourcing computations. Multiple representations.</td>
</tr>
</tbody>
</table>

137
| Explanation of categorization | Focus is on relationship between a function and its inverse. Requires interpretation of $f^{-1}(20)$ in terms of $f(a)$. | Plot of graph. Change of window size may be required. Use of Point Tool to get value of point desirable but not essential. | Task requires students to use non-algorithmic thinking; student is expected to explore and link mathematical concepts and relationships. | GeoGebra allows for the relatively easy generation of a graph of non-standard function. This would be very tedious by hand. Task requires student to focus on concept rather than manipulation. |

During the session the lecturers noticed that most students were trying to find the inverse of the given function analytically (an extremely challenging task given the particular function) or to generate the inverse with GeoGebra (again, a very difficult technical task with GeoGebra 3). The lecturers then reminded students that they did not need to generate $f^{-1}$ analytically or graphically in order to read off a specific value of $f^{-1}$ from the function $f$. This measure of scaffolding was insufficient for most students who were still not sure what to do. So one lecturer finally went to the board and demonstrated a possible approach to the task:

Assume $f$ has an inverse function, $f^{-1}$.

$f^{-1}(b) = a$

$\therefore f(a) = b$

This seemed to help many students and seven students, who previously seemed unable to move forward with the task, were able to complete the task with appropriate reasoning. See Table 2.

**Results**

Two students (Eva and Dawn) were able to argue, previous to the lecturer’s demonstration on the board, that since $f^{-1}(20) = a$, $f(a) = 20$. They then located 20 on the y-axis, and found the corresponding value of $x$, i.e., $f^{-1}(20)$. Their activity was classified as doing mathematics since they were able to use the relationship between domain and range of a function and its inverse to independently solve the problem.

Mandla’s imaginative approach to solving the problem was also classified as ‘doing mathematics’. He wrote:

```
"Equate $f$ to 20 and we have,
\[x^3 + x + 1 = 20\]
\[x^3 + x - 19 = 0.\]
```

---

6 All student names are pseudonyms.
Solution is where the graph cuts the x axis. Using GeoGebra the value is at $x = 2.54$. 

\[ \therefore f^{-1}(20) = 2.54 \].

This is a creative and non-algorithmic way of solving the problem; it was also done prior to the lecturer’s demonstration at the board.

Seven students (Jacob, Sipho, Lebo, Vince, Lisa, Lena, Thabo) were categorised as using ‘procedures with connections’. In all these cases, the lecturer had to tell the students individually, or using the board, that $f^{-1}(20) = a \Rightarrow f(a) = 20$ before the student was able to answer the question. So, for example, after watching the lecturer’s reasoning on the board, Lisa used GeoGebra to sketch graph of $f$. She then wrote:

“No we know that

\[ f(x) = y \]

\[ f^{-1}(y) = x \]

\[ \therefore f^{-1}(20) = a \Rightarrow f(a) = 20. \]

Look at the graph. $a$ is 2.5 when $f(a) = 20$. So $f^{-1}(20) = 2.5$’

Since some algebraic reasoning as well as some interpretation of the graph of $f$ was evident in this (and other similar arguments), these activities were classified as ‘procedures with connections’. That is, although students were given a strong hint on how to approach the problem, they still needed to make the link between this approach, the relationship between a function and its inverse and the value of $f^{-1}(20)$.

One student (Tom) merely wrote down the answer $f^{-1}(20) = 2.5$ with no evidence of algebraic reasoning. The researcher cannot possibly know what Tom was thinking (perhaps he had used reasoning to get to this answer; alternatively, having plotted the graph of $f$ and having listened to the lecturer’s explanation, he may have merely read off the value of $x$ for which $y = 20$). However, no reasoning was evident and so, in terms of the descriptions of the different types of cognitive demand, this activity was interpreted as a “procedure without connections”.

Two students (Shelley and Michael) did not show evidence of doing the task and so their activities could not be classified.

Table 2 summarises how each student implemented the given task. This analysis is done in terms of the mathematical focus as expressed through mathematical activity of the student; the extent to which the technical demands of the task were met by the student; the type of cognitive demand that the task apparently generated (as realized in the classroom for the student) and the extent to which the affordances of GeoGebra were exploited by that student.

<table>
<thead>
<tr>
<th>Eva</th>
<th>Mathematical focus</th>
<th>Technical demands</th>
<th>Cognitive demand (Stein)</th>
<th>Use of GeoGebra’s affordances</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Presented algebraic argument as to how to find $f^{-1}(20)$.</td>
<td>Met. Noted “it is a bit difficult to locate a point on</td>
<td>Doing mathematics</td>
<td>Used GeoGebra to sketch $f$. Moved between graphical and</td>
</tr>
<tr>
<td></td>
<td>Used GeoGebra graph of</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student</td>
<td>Description</td>
<td>Met</td>
<td>Doing mathematics</td>
<td>Used GeoGebra to sketch $y = x^2 + x - 19$. Moved between graphical and algebraic representations of $f$.</td>
</tr>
<tr>
<td>----------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-----</td>
<td>----------------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Mandla</td>
<td>Used algebraic argument to establish link between $f(x) = 20$ and root of $y = x^2 + x - 19$. Also used GeoGebra to sketch inverse of $f$ and so confirmed answer.</td>
<td>Met</td>
<td>Doing mathematics</td>
<td>Used GeoGebra to sketch $f$ and to confirm with graph of $f^{-1}$. Moved between graphical and algebraic representations of $f$.</td>
</tr>
<tr>
<td>Dawn</td>
<td>Presented algebraic argument as to how to find $f^{-1}(20)$. Used GeoGebra graph of $f$ to find $f^{-1}(20)$. Also used GeoGebra to sketch the inverse of $f$ (a complex and many-stepped technical procedure).</td>
<td>Met</td>
<td>Doing mathematics</td>
<td>Used GeoGebra graph of $f$ to sketch $f$ and to confirm with graph of $f^{-1}$. Moved between graphical and algebraic representations of $f$.</td>
</tr>
<tr>
<td>Lebo</td>
<td>First tried to find algebraic expression for $f^{-1}(x)$. After lecturer explanation at board, used GeoGebra successfully. Also justified answer algebraically.</td>
<td>Met</td>
<td>Procedures with connections</td>
<td>Used GeoGebra to sketch $f$. Moved between graphical and algebraic representations of $f$.</td>
</tr>
<tr>
<td>Lisa</td>
<td>Used GeoGebra graph of $f$ to find $f^{-1}(20)$ after lecturer explanation at board. Also justified answer algebraically.</td>
<td>Met</td>
<td>Procedures with connections</td>
<td>Used GeoGebra to sketch $f$. Moved between graphical and algebraic representations of $f$.</td>
</tr>
<tr>
<td>Vince</td>
<td>Used GeoGebra graph of $f$ to find $f^{-1}(20)$ after lecturer explanation at board. Also justified answer algebraically.</td>
<td>Met</td>
<td>Procedures with connections</td>
<td>Used GeoGebra to sketch $f$. Moved between graphical and algebraic representations of $f$.</td>
</tr>
<tr>
<td>Student</td>
<td>Description</td>
<td>Met</td>
<td>Procedures</td>
<td>Additional Information</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
<td>-----</td>
<td>------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Jacob</td>
<td>Used GeoGebra graph of $f$ to find $f^{-1}(20)$ after lecturer explanation at board. Also justified answer algebraically.</td>
<td>Met</td>
<td>Procedures with connections</td>
<td>Used GeoGebra to sketch $f$. Moved between graphical and algebraic representations of $f$.</td>
</tr>
<tr>
<td>Lena</td>
<td>Used GeoGebra graph of $f$ to find $f^{-1}(20)$ after lecturer explanation at board. Also justified answer algebraically.</td>
<td>Met</td>
<td>Procedures with connections</td>
<td>Used GeoGebra to sketch $f$. Moved between graphical and algebraic representations of $f$.</td>
</tr>
<tr>
<td>Sipho</td>
<td>Used GeoGebra graph of $f$ to find $f^{-1}(20)$ after lecturer explanation at board. Also justified answer algebraically.</td>
<td>Met</td>
<td>Procedures with connections</td>
<td>Used GeoGebra to sketch $f$. Moved between graphical and algebraic representations of $f$.</td>
</tr>
<tr>
<td>Thabo</td>
<td>Used GeoGebra graph of $f$ to find $f^{-1}(20)$ after lecturer explanation at board. Also justified answer algebraically.</td>
<td>Met</td>
<td>Procedures with connections</td>
<td>Used GeoGebra to sketch $f$. Moved between graphical and algebraic representations of $f$.</td>
</tr>
<tr>
<td>Tom</td>
<td>Wrote down value of $f^{-1}(20)$ after lecturer explanation at board. No justification provided.</td>
<td>Met</td>
<td>Procedures without connections</td>
<td>No evidence of algebraic reasoning or of use of graph.</td>
</tr>
<tr>
<td>Michael</td>
<td>No evidence of doing task</td>
<td>No evidence of doing task</td>
<td>No evidence of doing task</td>
<td>No evidence of doing task</td>
</tr>
<tr>
<td>Shelley</td>
<td>Did not attempt task.</td>
<td>No evidence of doing task</td>
<td>No evidence of doing task</td>
<td>No evidence of doing task</td>
</tr>
</tbody>
</table>

**Discussion**
The use of Berger’s framework for analysis of a computer-based task illuminates crucial aspects of the task and discrepancies between the intended pedagogical purpose of the task and its actual execution. For example, it is clear from the analysis of students’ activities (other than two students who did not show evidence of doing the task) that the technical demands of the task were appropriate to the students’ abilities. All students (save for two who did not give evidence of generating a graph) were able to plot the given function. Thus, in this task, the a priori analysis of the technical demands of task were congruent with the actual demands for most students. This is not always the case. Tasks where the technical demands are too high for the students may result in a substantial lowering of the cognitive demand of the task since the student is unable to perform the requisite technical procedures to even embark on the given task.

The intended mathematical focus of the task – the relationship between the domain and range of a function and its inverse – seemed to move out and into view for most students other than the three ‘doing mathematics’ students who were able to solve the task without any assistance. The lecturer’s intervention (comprising of the explanation that \( f^{-1}(b) = a \Rightarrow f(a) = b \)) seemed to bring this relationship into view for most students (the seven ‘procedures with connections’ students). Thus the lecturer’s mediation enabled these students to complete the task with justification of their reasoning. Notwithstanding this opening up of the task, this intervention lowered the cognitive demand of the task. This is discussed further below. Possibly the two students who showed no evidence of attempting the task never had this focus and the lecturer’s mediation did not help sufficiently.

With regard to the technological affordances of GeoGebra, the a priori analysis suggests that GeoGebra could be used to outsource computation and to provide multiple representations. Both of these affordances were realized: most students used GeoGebra to draw the function \( f \) (outsourcing computation) and most students, other than possibly, Tom, Michael and Shelley, moved between the algebraic relationship of \( f(a) \) and \( f^{-1}(20) \) and the graphical representation of \( f \) to extract the value of \( f^{-1}(20) \) (multiple representations).

From the above results, it is clear that different students performed the task in different ways and different students extracted different benefits and levels of challenge from this same task. Similar to the study by Stein et al (1996), the cognitive demand of the task decreased as a result of the lecturer’s intervention for seven students. These students were not classified as ‘doing mathematics’ since they had not generated a pathway through the problem by themselves. Rather it was the lecturer’s on-board explanation that \( f^{-1}(a) = b \Rightarrow f(a) = b \) that helped the students to notice (Mason & Johnston-Wilder, 2006) that the \( x \)-value corresponding to \( y = 20 \) (obtained from the graph of \( f \)) was the required answer. After noticing this, these students were able to use algebraic reasoning to show that \( f(a) = 20 \). Subsequently they were able to use this to usefully interpret the graph of \( f \). Since they were executing procedures which required and contributed to conceptual understanding of the relationship between a function and its inverse, the cognitive level of the task was classified ‘procedures with connections’. Perhaps these students would have benefitted from a background task which compelled them to examine directly the relationship between values in the domain of a function and corresponding values in the range of the inverse function (and vice versa).

One student, Tom, merely wrote down the final answer: \( f^{-1}(20) = 2.58 \) with no evident algebraic reasoning. In this task, Tom did not partake in the classroom norm of justifying one’s answer. Perhaps Tom would have benefitted from a direct instruction to explain how he got his answer. But such an instruction would have been superfluous for most of the class.
Furthermore as researcher I can not know whether Tom did, in fact, use algebraic reasoning to perform this task. However given that this reasoning was not evident, Tom’s response is classified as “procedures without connections” in terms of the framework and the classroom norms.

Two students showed no evidence of doing the task. Given that they were both very weak students, I suspect that their prior knowledge did not allow for epistemological access to the task. The sort of mediation that would be required in such a case would be preliminary tasks and definitions and examples which gently introduced the notion of an inverse function. In Vygotskian terms, this task was not in these students’ zone of proximal development. Recognizing this possibility is a first step; it does not solve the problem of how to deal with heterogeneous classes in which different tasks or slight modifications of a task may be more suited to different students’ zpds.

Conclusion
The framework is useful for aligning the design of a task with its implementation by the students. For example, based on the misalignment between the intended pedagogic purpose of the task (as documented in the a priori analysis) and the actual realization of the task (as documented in the a posteriori analysis), consideration could be given to how the task design could be modified in future. At the same time, the analysis shows quite clearly that in a classroom situation, there are tensions between the differing needs of different students and the maintaining of an optimum cognitive demand for all students for any particular task. That is, some students may require more scaffolding than others when engaging with a task. As has been argued elsewhere (see Stein et al, 1996), this scaffolding may reduce the cognitive demand of the task for these or other students.

The use of the framework for task analysis both as an a priori tool and as an a posteriori tool also illuminates congruencies and discrepancies between the intended task and its execution by different students. Although a task may be designed with one pedagogic purpose in mind, the teacher/lecturer needs to be aware that different students will engage differently with the task and the same task may engender very different types of mathematical thinking in different students.

In conclusion, the relationship between the level of scaffolding (written or front-of-class or individual) and the need for challenging, relatively unscaffolded questions which stimulate and provoke students’ mathematical thinking, requires a delicate balance, and further investigation.
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An Assessment of theory of computation in computer science curricula

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Abstract
Computing curricula are regularly reassessed and updated to reflect changes in the discipline. Currently, the ACM/IEEE curriculum ‘CS2013’ is under review, which provides the main international guiding principles for curriculum development. We assess this curriculum focusing on one of the core themes of computer science, being Theory of Computation. We examine how it is implemented in computer science curricula around the world, and the sentiment around teaching it. Two surveys were conducted, examining curricula and syllabi of computer science degrees and an online opinion survey. Theory of Computation is part of 84% of the consulted curricula around the world, but taught at only 27% of the South African universities, and these syllabi contain substantially more Theory of Computation topics than the basic core in CS2013. The online survey not only confirms this but also indicates inclusion of even more topics as essential for Theory of Computation and shows that it is mostly solidly part of the degree programme as a core course and mostly in the 2nd or 3rd year, despite that for more than half of the respondents, the course causes issues in the university system.

Introduction
Computing skills are designated as scarce skills, yet it is important not only to produce more computer science graduates, but also of a high quality so that graduates are equipped with the capabilities to design novel IT solutions for the Southern African context. Currently, there is no South(ern) African computing organisation for quality and curriculum guidance and accreditation to assist with this, hence one is left with considering international efforts and adapt it to the regional context (Marshall, 2011). The main international organisations for Computer Science (CS), such as the US-oriented Association for Computing Machinery (ACM) and the International Federation for Information Processing (IFIP), conduct periodic updates to the CS curricula. A landmark publication in 1989 by the ACM defined the CS discipline and curriculum topics (Denning et al, 1989), which was followed by an internationally more inclusive and much more detailed list of topics and the notion of ‘modular curriculum’ by (UNESCO-IFIP, 1994), which was followed by the UNESCO-IFIP “ICF-2000” curriculum and “CC2001” by the ACM (Roberts, 2002). Currently, the ACM/IEEE “CS2013” is under public review (ACM/IEEE Joint Task Force on Computing Curricula, 2012; Sahimi, Aiken & Zalenski, 2010; Sahimi et al, 2012), which, as notable change to its predecessors, recognises the diversification within CS beyond the simple hardware/software/IT divides, and describes learning outcomes. A central theme is what falls under the banner of Theory of Computation (ToC)—being, roughly, formal languages, automata, Turing machines, computability, and complexity—that introduces the mathematical and computational principles that are the foundations of CS, such as the foundations of programming languages and algorithms, and the limits of computation; typical textbooks are Sipser (1997) and Hopcroft, Mottwani & Ullman (2007). These themes are mostly taught in at least one basic undergraduate course (module), but also can be split over two or more courses, such as automata in a compilers course and complexity jointly with algorithms. These topics were core in the original curriculum guidelines (Denning et al, 1989; UNESCO-IFIP, 1994), but CC2001 and CS2013 have divided that into a smaller core and a
set of elective topics, which contributes to a steady flow of anecdotes about ‘dumping down’ of CS degrees (e.g., (Dijkstra, 1988; Dewar & Schonberg, 2008)). The ACM/IEEE and UNESCO-IFIP curriculum guidelines are, however, not to be understood as templates for course design, evaluation of subjects, teaching and learning principles, or criteria for accreditation, but principally as a guideline by means of a list of required and recommended undergraduate degree contents (van Veen, Mulder & Lemmen, 2004). Given the observed difference in emphasis on ToC in the international curricula guidelines over time and the pending update on the ACM/IEEE curriculum—as well as curriculum update discussions at the author’s institution and elsewhere, e.g., (Sahimi, Aiken & Zalenski, 2010)—it is useful to assess 1) how ToC topics are implemented in CS curricula around the world at present, 2) whether there are any country or regional differences, and 3) what the sentiment is around teaching ToC in academia that may influence the former.

To gain insight in these three aspects, we conducted two surveys, which, to the best of our knowledge, are the first of its kind. The first survey examines syllabi of CS degrees as published online on the respective universities’ websites with respect to ToC. The second survey was an online survey open to everybody, which asked for the respondents’ opinions on ToC, the context in which it is taught, and what topics should be in a ToC course. The salient outcomes are that ToC is included in the vast majority of the consulted CS curricula around the world, except for South Africa, and these syllabi contain substantially more ToC topics than the basic core of CS2013. The online survey confirms this, and, moreover, the respondents generally include even more topics as ‘essential’ than that are given in the syllabi. Also, most respondents did do ToC and it is being taught at most of the universities with which the respondents are affiliated, and it is solidly part of the degree programme in the majority of responses. The opinion survey also highlights that there are difficulties in teaching ToC, exhibited by, among others, relatively high failure rates or other issues in the university system.

In the remainder of the paper, we first describe the materials and methods of the surveys, followed by the results and a discussion, and then we conclude.

Materials and methods
The survey is divided into two components: the survey of extant curricula and syllabi and the online opinion survey. Limitations of the set-up will be addressed in the discussion section.

Curriculum and syllabi survey
General set-up. A selection of universities will be made, with a focus on all South African universities designated as ‘traditional’ or ‘comprehensive’, and from each major region in the world a subset of universities is pre-selected. The aggregations for the latter are: Africa outside South Africa, Asia, Latin America, Europe (continent, west), and the discontiguous region of Anglo-Saxon countries (Australia, Canada, New Zealand, UK, USA). The selection of the international universities is based roughly on inclusion in the Times Higher Education Ranking for countries unfamiliar to the authors. Of those regions and countries, only those will be assessed that have a website and a curriculum understandable in any of the languages that the author understands sufficiently in order to conduct the data collection (being, in alphabetical order: Afrikaans, Dutch, English, German, Italian, Portuguese, and Spanish).

Data collection. Parameters to record are: region, country, type of university (where applicable), whether ToC is included in a degree programme in whole or in part or not, and if so in which year of the degree programme, and analysis of content of the syllabi (if present).

Opinion survey
General set-up. The method chosen for this survey is that of an open online questionnaire for a two-week time period. Both individual email invitations are to be sent to colleagues inside and outside the University of KwaZulu-Natal, an announcement on the Description Logics and UKZN/CSIR-Meraka Centre for Artificial Intelligence Research mailing lists, and social media will be used as well (the author’s Facebook and Google+ accounts). Respondents can leave their email to be contacted for further questions and feedback. The survey software used is LimeSurvey, because it is free survey software that has the necessary feature of conditional questions and extensive branching. Analysis of the results will be carried out with the built-in LimeSurvey features and Microsoft Excel.

Survey Questions. The survey consists of eight main questions, with conditional questions depending on the answer provided by the respondent. They are summarised here.

1. Should Theory of Computation [roughly: formal languages, automata, complexity] be a course in a CS programme?
   a. If yes: core or elective, undergraduate or postgraduate, when in the programme (undergrad (1, 2, 3), honours(4), MSc, PhD)?
2. Is it taught at your university?
   a. If no: was it, but cancelled? If yes: Why?
   b. If yes: core or elective, when in the programme (undergrad (1, 2, 3), honours(4), MSc, PhD), is it secure/solidly in the programme or threatened to be cancelled, does it cause ‘problems’ such as being flagged for low pass rates or negative student evaluations? Participation (indication): estimate of average amount of enrolled students in each course offering over the past 3 years (<10; 10-30; 31-60; 61-100; more than 100), is the amount stable or in decline (stable, slight decline, strong decline (>50% fewer students in past 5 years)). First-time pass rate (<20, 20-40, 41-60, 61-80, 80-100%).
3. Did you ever teach, or are currently teaching, Theory of Computation or Formal languages and automata only or Computability, complexity only?
4. Did you do Theory of Computation in your degree? If yes: which year of the programme? If no: do you miss it/regret not having done so?
5. Do you do research in Theory of Computation topics? Do you use Theory of Computation topics in research or at work?
6. Our survey of syllabi indicates some differences across universities. Please indicate for the following topics whether you consider the topic ‘essential’, suitable for an ‘extended version’ of a ToC course, or ‘peripheral/may be skipped’. (For reasons of brevity, the full list of 46 topics in included in the results section only.)
7. Comments the respondent wishes to make, name of the organisation where the respondent works/studies, email (optional).

Results
In line with the two surveys, the results will be presented separately.

Computer science curriculum and syllabi survey results
Countries and Universities. The full list of universities consulted is included in the appendix; they are 17 universities from South Africa, 15 from Europe, 15 from the Anglo-Saxon countries, 6 from Asia, 7 from Africa other than South Africa, and 8 from Latin America. The
lower amounts for Africa, Asia, and Latin America is largely due to the language barrier and that they generally have less information online, except for the relatively famous (and rated) ones. A total of 9 universities had no or insufficient data online to assess ToC in the curriculum, being two in South Africa (Limpopo and Venda) and 7 in Asia, Africa, and Latin America.

**ToC in the curriculum.** The inclusion of ToC in part or in whole in the CS curricula of the South African universities that had such information online \( (n=15) \) with that of the consulted universities in the rest of the world that had such information online \( (n=44) \) is compared in Figure 1. More precisely: 27% of the South African universities—University of KwaZulu-Natal, University of South Africa, University of Western Cape, University of Witwatersrand—has ToC in the CS curriculum compared to 84% elsewhere in the world.

**Figure 1.** Comparison of ToC in the CS curriculum in South Africa and in other countries. (FLAT=formal languages and automata theory)

Disaggregating the “other countries” by the identified regions and including also those universities consulted for which no or insufficient material was available online, we see a similar picture (see Figure 2). The African universities consulted that include ToC in the curriculum are Alexandria, Makerere, Zimbabwe, Lagos, and Kenyatta partially, whereas for Botswana, and Addis Ababa no information was available online. The absence of online information was also an issue for the Latin American universities, but, given their responses on the opinion survey (see below), it definitely will amount to a higher percentage than is currently included in the syllabi data. This is unclear for Asia.

**Figure 2.** Curriculum evaluation on inclusion of ToC, disaggregated by region outside South Africa.

The difference between Europe (93% inclusion of ToC) and the Anglo-Saxon countries (80%) may be an artefact of the sample size, but it deserves further analysis with larger sample sizes.
The level of consistency of presenting information online about curricula and/or course listings and/or course descriptions and/or detailed syllabi varied widely, and in several cases multiple options applied. For instance, ToC being core in one ‘track’ or ‘stream’, but not another, or for some students scheduled in the BSc and others in the MSc programme. There were 43 universities (of the 59 with data) that had sufficient information online regarding timing of ToC in the degree programme. Of those, only 5 had it explicitly in the MSc degree programme, with the rest mainly in year 2, 3, or 4. Five universities that offer ToC have it spread over 2 or more courses, and the rest offers it in a single course (occasionally, additional advanced courses covering advanced topics such as probabilistic automata and other complexity classes). An initial attempt was made to categorise the topics of the syllabi in more detail, but this was abandoned due to the high variability of detail of such information being online.

Opinion survey results
Characterisation of respondents. The number of completed surveys was 77, of which 58 filled in their affiliation. The respondents are mainly employed at universities and research institutes: 12 respondents indicated an academic affiliation in South Africa (Stellenbosch, KwaZulu-Natal, UNISA, Pretoria, Witwatersrand) and thus the majority of respondents were from around the world, including universities of Illinois, Rutgers [US], Waterloo [CA], Bolzano [IT], Dresden [DE], Geneva [CH], Southampton [UK], Ben Gurion [IL], Bahía Blanca [AR], CENATAV [CU], Pontificia [CL/BR], São Paolo, Rio de Janeiro, Sergipe, Espírito Santo, and 8 others from [BR], Macau [CN] and Indonesia [ID], and at least three respondents are employed in industry (Boeing, Google, and SRI International). 35 respondents indicated to have taught ToC, 37 formal languages and automata only, 25 computability and complexity, and 16 closely related courses such as algorithms, logic, and compilers. 41% of the respondents (32) conducts research in ToC topics and 72% (56) use it in research or other work (including 2 from the aforementioned companies). Twelve respondents neither conduct research in ToC topics nor use it. The spread of respondents is too broad to merit statistical analyses about whether responses vary significantly by country, by continent, or by predominant language at the organization.

Answers relating to ToC. The anonymized raw question answers with percentages, sorted by question (exported from Lime Survey) are online at http://www.meteck.org/files/tocsurvey/, and anonymized answers to each survey question in per-question-format with answers by respondent as a spreadsheet are available upon request; the following paragraphs summarise the results.

The basic ToC course statistics are as follows. 76 of the 77 respondents are of the opinion ToC should be in programme, 74 (96% of the answers) have it currently in the programme, and 82% had it in their degree programme when they were a student. Of those 14 who did not do ToC during their studies, 86% misses not having had that opportunity and the remaining respondent did not do ToC, does not miss it not having done so, said that it should not be in the programme, and never uses it at work.

Considering when it should be taught in the degree programme, and taking note of the 10 comments in the comments field of the survey describing it has been divided over several courses, there was a clear tendency for undergraduate compared to honours, MSc, or PhD (ratio yes/no 0.69 for undergrad versus 0.45 for honours and 0.33 for MSc/PhD), and the 3rd year in particular (ratio yes/no year1 0.13, year2 1.03, and year3 1.57). This roughly corresponds to when the respondents themselves did ToC and when it is taught at the
university. Given there must be several calendar years difference between being a student and that the survey respondents are graduated since a while (see previous paragraph), there is thus little change over the years, as can be seen in Figure 3. The 5% increase in teaching ToC in year 3 comes mainly from the decrease in honours/year 4 and PhD.

Figure 3. Comparison between the year the survey respondents did ToC in their studies and when the study programme was taught at their university (where applicable).

ToC is a core course in the curriculum in 67 of the 74 answers (90%), and secure in the programme for 57 out of 66 responses (86%). Only few reasons were provided for “under threat/other”, being that it has been removed from some specialisations but not all (in part, due to the computer science vs. information systems tensions, as elaborated on by one respondent), or threatened due to low enrolment numbers, resulting in one case ToC being taught only every other year. Enrolment numbers vary greatly, from less than 10 students (6% of respondents) to classes with more than 100 students (16%), with the main 31-60 students/year (40%) and then 11-30 students (24%). 25% (15 of 60) record a slight decline in enrolment.

Given the plentiful anecdotes, hearsay, and assertions in other ToC teaching papers about difficulties with ToC teaching and learning, we also asked about that in the survey. The data provided by the respondents do substantiate the existence of issues to some extent. While 44% of the respondents answered that there are no issues and everything runs smoothly, 32% note it causes problems in the academic system each year and another 24% reported that management/student affairs has gotten used to the fact there are problems, i.e., a slight majority of respondents faces issues. Several respondents provided additional information regarding the issues, mentioning low pass rates (3), that students struggle because they do not see the usefulness of ToC for their career (4), that it also depends on the quality of the teacher (2), and low enrolment numbers (2). We considered three variables present in the result set that may influence there being issues: pass rates, class size, and content of the course. Course content was extrapolated from the answers given to the ToC topics, where more topics denoted as ‘essential’ was assumed to result in a heavier course load, which need not be the case, and no correlation was found. Data on the interaction between pass rates, participation, and issues were analysed: for 45%, the first-time pass rates remain below 60% and with 80% of the respondents, the pass rate remains below 80%. There is no clear trend between pass rate, class size and issues, except that pass rate 41-60% and class size 31-60 have comparatively more issues (72% and 64% of the reported instances, respectively), and that the correlation between pass rate and issues is 0.79; n is to small to draw any conclusions for the other combinations.

ToC topics. The final set of main questions concerned the topics that should be part of a ToC course. 46 topics were listed and for each one, the answer [essential/extended/peripheral/no answer] could be given. The responses were analysed in two different ways: calculating the percentage of a response value out of the total responses given and by assigning values to the
responses (essential = 3, extended = 2, peripheral = 1) and ordering topics according to the average over the given answers. The order of the topics is roughly the same for the essential topics and varies only by a few places at the tail end; thus, there is a consensus about which topics are important regardless the measure. The complete list of ToC topics ordered on percent ‘essential’ is shown in Table 1.

Table 1. Ordering of the 46 ToC topics, by calculating the percentage of responses that marked it as ‘essential’ out of the given answers.

<table>
<thead>
<tr>
<th>Topics ordered on percent ‘essential’</th>
<th>cont’d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular expressions</td>
<td>98.55</td>
</tr>
<tr>
<td>Deterministic Finite Automata (DFA)</td>
<td>95.71</td>
</tr>
<tr>
<td>The Turing Machine (basics)</td>
<td>94.37</td>
</tr>
<tr>
<td>Context-free Grammars (definition, ambiguity, simplification, derivations)</td>
<td>94.20</td>
</tr>
<tr>
<td>Non-Deterministic Finite Automata (NFA, epsilon-NFA)</td>
<td>88.41</td>
</tr>
<tr>
<td>Equivalences &amp; conversion RE and automata</td>
<td>85.29</td>
</tr>
<tr>
<td>Problems a computer cannot solve</td>
<td>85.29</td>
</tr>
<tr>
<td>Halting problem</td>
<td>82.81</td>
</tr>
<tr>
<td>Properties of Regular languages</td>
<td>80.30</td>
</tr>
<tr>
<td>Regular grammars (RG)</td>
<td>80.00</td>
</tr>
<tr>
<td>Examples of some undecidable problems/languages</td>
<td>78.13</td>
</tr>
<tr>
<td>Church-Turing thesis</td>
<td>77.94</td>
</tr>
<tr>
<td>Computability and decidability</td>
<td>76.81</td>
</tr>
<tr>
<td>Equivalences &amp; conversion DFA, NFA, epsilon-NFA</td>
<td>73.85</td>
</tr>
<tr>
<td>P, NP, NP-complete, NP-hard, co-NP</td>
<td>73.53</td>
</tr>
<tr>
<td>Universal Turing Machine</td>
<td>72.06</td>
</tr>
<tr>
<td>Undecidability</td>
<td>68.57</td>
</tr>
<tr>
<td>Pumping lemma for Regular languages</td>
<td>68.18</td>
</tr>
<tr>
<td>Some well-known NP problems (e.g., TSP, SAT, Node cover)</td>
<td>68.18</td>
</tr>
<tr>
<td>Chomsky normal form, hierarchy</td>
<td>67.16</td>
</tr>
<tr>
<td>Reductions</td>
<td>65.15</td>
</tr>
<tr>
<td>Proving Undecidability</td>
<td>62.86</td>
</tr>
<tr>
<td>Show problem to be decidable/undecidable(RE, non-RE, RE but not Rec.)</td>
<td>61.90</td>
</tr>
<tr>
<td>Push-down Automata (PDA, deterministic and non-deterministic)</td>
<td>61.54</td>
</tr>
<tr>
<td>Converting RG NFAs</td>
<td>60.61</td>
</tr>
<tr>
<td>TM acceptors</td>
<td>57.14</td>
</tr>
<tr>
<td>Pumping lemma for CFLs</td>
<td>54.69</td>
</tr>
<tr>
<td>Equivalences &amp; conversion PDA, CFG</td>
<td>51.61</td>
</tr>
<tr>
<td>Show problem to be P, NP, NP-complete, NP-hard, co-NP</td>
<td>50.75</td>
</tr>
<tr>
<td>State minimization</td>
<td>49.25</td>
</tr>
<tr>
<td>Closure properties of CFLs</td>
<td>49.21</td>
</tr>
<tr>
<td>Recursively Enumerable, non-RE, RE but not recursive languages</td>
<td>46.38</td>
</tr>
<tr>
<td>Decision properties of CFLs</td>
<td>46.03</td>
</tr>
<tr>
<td>Multi-tape TM</td>
<td>30.88</td>
</tr>
<tr>
<td>Rice’s theorem</td>
<td>30.00</td>
</tr>
<tr>
<td>Post correspondence problem</td>
<td>26.67</td>
</tr>
<tr>
<td>PSPACE, EXPTIME, ...</td>
<td>26.23</td>
</tr>
<tr>
<td>Moore Machines</td>
<td>21.31</td>
</tr>
<tr>
<td>Mealy Machines</td>
<td>21.31</td>
</tr>
<tr>
<td>Programming tricks for TM (storage, tracks)</td>
<td>20.59</td>
</tr>
<tr>
<td>TM transducers</td>
<td>17.74</td>
</tr>
</tbody>
</table>
Polynomial time reductions 62.69  Hot/fun topics and their complexity 15.87  
classes (e.g., games)

Topics that received most (50-60%) ‘In an extended course’ are: TM transducers; Post correspondence problem; PSPACE, EXPTIME, ...; hot/fun topics and their complexity classes (e.g., games); ‘programming tricks’ for TM (storage, tracks); and Cook’s theorem. Four respondents used the comments field to add other topics, being: weighted automata and transducers with applications in a basic course and tree automata in an extended course, Quantum Turing Machine, Savitch Theorem, PSPACE-completeness, and parallel complexity classes with PRAM NC P-complete.

Discussion

The responses of the opinion survey—77 being a substantial amount for an open survey—show an overwhelming agreement about the need for a ToC course in a CS degree programme, regardless whether they have done the course themselves, teach or have taught it or a similar course, or conduct research in it, or do not use it at all. As such, it re-confirms ToC’s place in the curriculum from the perspective of, mostly, academics.

Concerning topics of a ToC course, it is perceived decidedly that formal languages, automata, Turing machines, complexity, computability and decidability themes form part of one coherent offering, but that the detail of the sub-topics covered may vary. For instance, including Turing machines in a basic ToC course, but transducers, storage and tracks only in an extended or advanced ToC course, including Deterministic and Non-Deterministic Finite Automata, but not Mealy and Moore machines, and covering Context-Free Grammars, but not decision and closure properties. This contrasts quite markedly with the Strawman/CS2013 outline, which is depicted in Figure 4.

Figure 4. Proposed CS2013’s ToC topics in the Strawman draft (layout edited).

However, the feasibility of imparting a real understanding of complexity classes P and NP without also touching upon computability and Turing machines is limited. In addition, the hours indicated in Figure 4 have to be understood as minimum hours of fact-to-face lectures, which amounts to 8 lessons at a South African university (8 * 45 mins = 6 * 60 mins), or at
least almost 3 weeks of a standard 16 credit semester course, which, if this minimum is adhered to, amounts to a very superficial treatment of partial ToC topics. We focus explicitly on CS programmes, which should have most time dedicated to ToC compared to other computing specialisations, but even then, the voices from the field clearly demonstrate putting a higher weight on ToC than the ACM/IEEE curriculum developers allot to it. Why could this be so? Arguments can be heard that ToC matters more for CS than other recently recognised specialisations within computing—e.g., software engineering, net-centric computing, information systems, and computational biology—, that this diversification has to be recognised by the curriculum developers (Rosenbloom, 2004; Sahimi et al, 2012), and that it should result in putting more or less weight on the core topics (see (ACM/IEEE Joint Task Force on Computing Curricula, 2005) for a detailed analysis on sub-disciplines within computing and a proposed weighting of curriculum themes). This is not reflected as such in the Strawman draft: the different tracks within CS all have to do the core, with 100% for tier-1 and >80% of tier-2 core, and an undefined amount of the elective topics to facilitate track-development, although no tracks have been defined in the CS2013 yet. It is noticeable only when one compares it with the Software Engineering curriculum guidelines (ACM/IEEE Joint Task Force on Computing Curricula, 2004), as those guidelines include only a little bit on finite state machines, grammars, and complexity and computability in the “Data structures and algorithms” and “Discrete structures II” themes. It may be the case that, in praxis, those degree programmes called “computer science” indeed do contain the more fundamental topics, such as ToC (and logic, formal methods etc.), and that other ‘tracks’ actually have been given different names already, hence, would have been filtered out unintentionally a priori in the data collection stage of the curriculum survey.

Concerning issues teaching ToC, on an absolute scale, that 56% faces issues with their ToC courses is substantial. It deserves a comparative analysis to uncover what the other half does so as to not have such issues. Comments in the survey and offline (in the form of follow-up emails) by survey respondents suggest it may help to demonstrate better the applicability of ToC topics in the students’ prospective career, have experienced good teachers, and appropriate preparation in prior courses to increase the pass rates. Further, it might be related to the quantity and depth of material covered in a ToC course with respect to nominal course load. The data hints also to another possible explanation: even with a 80-100% pass rate and no low enrolment the ‘gotten used to the issues’ was selected occasionally, and vv., with a 41-60% pass rate that everything runs smoothly, thereby indicating that having issues might also be relative to a particular university culture and expectations of students, academics, and management.

Addressing possible limitations of the survey set-up. There are several limitations of the set up of the surveys that may affect the results. First, the non-South African universities were selected largely based on reputation, such as the Times Higher Education Ranking, to the extent one might ponder whether the fact that it is skewed toward the ‘good’ universities may have an effect, and one might argue that they include ToC because they have a good insight in designing a high quality curriculum. Or, that the sample is too focussed on education systems in ‘the West’—which holds for the syllabus survey, but not the opinion survey—and that such curricula are, or have to be, adapted to the local context in a yet to be specified way. The latter ought not to entail omitting core material from a discipline’s curriculum anyway, and, moreover, CS and development of novel and good quality software requires an understanding of ToC topics; e.g., in order to develop a correct isiZulu grammar checker or parser, scalable image pattern recognition algorithms to monitor wildlife tracks with pictures taken in situ, or an ontology-driven user interface for the South African Department of
Science & Technology’s National Recordal System for indigenous knowledge management. These are broad-sweeping statements and this research does not provide, and did not aim to provide, an answer to these questions. Second, when there were detailed syllabi, they often did not provide detail regarding the hours spent on each topic and no credit comparison was made, which can introduce a larger variability than what is presented in the results. A case in point is the detailed evaluation of the curricula by academics from Imperial College London, TU Delft, ETH Zurich, and RWTH Aachen that gave ToC a relative importance of 10%, 7%, 4.5%, and 9.3%, respectively (IDEA League, 2001). However, this does not change the substantial difference between the presence/absence of ToC in the curricula in South Africa versus in other countries.

Regarding the opinion survey, the distribution of the invitations was skewed toward fellow scientists who work in similar fields, both regarding individual emails and the distribution lists, most of whom use, or know they benefit from, ToC topics in their work, and perhaps a bit skewed toward computability and decidability as most important topics. Also, it is an open survey, hence, it may exhibit the tendency that those who are more passionate about ToC will be the main proportion of respondents. However, the cross-check with the curricula and syllabi survey did not demonstrate a clear difference, and the necessity of including at least complexity is also reflected in the Strawman/CS2013 draft; hence, the opinion survey does not indicate the existence of this possible bias. Moreover, the respondents come from each continent of the world and from many different universities, therewith providing a valuable snapshot of various aspects of ToC, in particular regarding the basic ToC course statistics, perceived importance of topics, and data about prevalence of issues, which is, to the best of our knowledge, the first of its kind.

Returning now to the original three questions posed in the introduction, we can answer them as follows. Regarding the first question, on how ToC is implemented, it can be observed that ToC topics in the actual international curricula are more in line with the older curriculum guidelines of Denning et al (1989) and UNESCO-IFIP (1994) than the more recent versions that put less weight on ToC topics. The timing in the curriculum regarding when to teach ToC remains largely stable. The results show there are country/regional differences, with the most pronounced one being that ToC is taught at only 27% of the South African traditional and comprehensive universities versus its inclusion in 84% of the consulted curricula elsewhere in the world. Even including the ones with partial ToC coverage does not make up for the differences with elsewhere in the world and any of the proposed curriculum guidelines. Other geographic or language-based differences are not deducible from the data, or: based on the data, region does not matter substantially regarding inclusion of ToC in the CS curriculum, except that the slight difference between Europe and the Anglo-Saxon countries deserves further attention. Opinion on ToC is overwhelmingly in favour of having it in the curriculum, and primarily in the 2nd or 3rd year. Also, a large list of topics is considered to be ‘essential’ to the course, and this list is more inclusive than the recent international curricula Strawman drafts’ core for ToC topics. Despite noted issues with the course, the voices from the field clearly indicate that ToC is here to stay.

Conclusions
Both the survey of the international curricula and syllabi and the opinion survey show an overwhelming agreement that Theory of Computation should be taught and is being taught, and a majority has it scheduled in the 2nd or 3rd year in an undergraduate computer science programme. The course is mostly solidly in the programme as a core course. There is
agreement on the typical topics that are considered as essential to Theory of Computation, covering regular and context-free languages, automata, Turing machines, undecidability, computability and complexity, where the subtopics covered vary. This is in line with older computing curricula guidelines, but less so with recent proposals that, comparatively, downplay Theory of Computation topics even for pure/‘majoring in’ computer science curricula in favour of a smaller core and multiple tracks. About half of the respondents note there are issues with the course, for various reasons, including, but not limited to, low pass rates and low enrolment, where roughly half observe first-time pass rates below 60%. This nevertheless does not to have an effect on the curricula thus far.

Given that, practically, Theory of Computation is solidly in the CS degree programme, and perhaps ought to be introduced more widely in South Africa, our future line of work pertains to assessing reasons behind the noted issues with teaching Theory of Computation, and what makes the course successful and running smoothly in some cases, including aiming to obtain a better specification of its prerequisites, and therewith other undergraduate courses.

References


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We are grateful for all the people who took the time to fill in the survey, and especially those who provided additional offline/email feedback and information. We also would like to thank Leonard Els for setting up the survey software.

Appendix A: Universities consulted for the syllabi survey

South African universities (17): UCT, UFH, UFS, UKZN, Limpopo, NWU, UP, RU, Stellenbosch, UWC, Wits, UJ, NMMU, Unisa, Univen, WSU, UniZulu.

European (continent, west) universities (15): Free University of Bozen-Bolzano and “la Sapienza” University of Rome [IT], Technical University of Dresden, Technical University of Rhine-Westphalia in Aachen (RWTH Aachen), and Technical University of Munich [DE], Free University of Amsterdam and Technical University of Eindhoven [NL], Catholic University Louvain and Ghent University [BE], Vienna University of Technology [AT], Linköping University [SE], ETH Zurich and EPFL [CH], Polytechnic University of Madrid and Polytechnic University of Catalonia [ES].

Universities in Anglo-Saxon countries (15): Oxford University, Manchester, and University of Edinburgh [UK], Toronto and Vancouver UBC [CA], MIT, Stanford, Penn State, Yale, Harvard, Stony Brook, and CMU [USA], University of Melbourne and Australian National University [AU], and the University of Auckland [NZ].

Asian universities (6): University of Malaya [MY], National University of Singapore, Peking university and the University of Hong Kong [CN], University of Tokyo [JP], and the Indian Institute of Technology, Bombay.

African (non-SA) universities (7): Alexandria University [EG], Makerere [UG], University of Zimbabwe, University of Lagos [NG], Kenyatta University [KE], University of Botswana, and Addis Ababa University [ET].

Latin American universities (8): UCI and University of Havana [CU], Bolivarian University of Venezuela, Pontifical University of Chile and University of Chile, State University of Campinas and University of São Paolo [BR], and National Autonomous University of Mexico.
Integrating visual and analytical strategies: An analysis of grade 11 learners’ problem solving approaches to a reflective symmetry task.

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No soul thinks without a mental image – Aristotle

Abstract
Learner ability to integrate visual and analytical skills when solving problems is espoused in mathematics education hence it has been put on the spotlight both locally and internationally. In this paper I analyse learner responses to a transformation geometry task which had the potential of being solved from both a visual and an analytic approach. A visual - analytic model is used to describe learner responses. Specifically, the paper aims at understanding which approach learners preferred, whether the approach was used efficiently and whether or not any attempts were made to integrate the approaches. The analyses revealed that learners used the visual approach predominantly; they did so inefficiently and there were no indications of integrating the approaches. Similar findings have been documented and attributed to how reflective symmetry is introduced to learners. This underlines the problem with an approach to teaching which stresses visual appreciation disconnected from formalisation.

Introduction
Mathematics education research has long debated the relative presence and value of visual versus analytic elements of mathematical thinking (Zazkis, Dubinsky & Dautermann, 1996). Generally the debates tend to dichotomise visual and analytical thinking with some arguing that the use of visual strategies were elementary/primitive and connected with weak mathematical ability (Kossylyn, 1980), while others argued that imagery or visualization was in fact an act of analysis or proof in that an individual uses markers for mental objects thereby establishing some connection between an internal construct and something accessible through the senses (Harries & Barmby, 2006). Presmeg’s (1986; 2006) work on the other hand, suggested ways in which logical rationality is intertwined between visual and analytical thinking. He argued that concrete (visual) imagery needs to be coupled with rigorous analytical thought processes if they are to be effectively used in problem solving (Presmeg, 1986; 2006). Similarly, Zazkis, Dubinsky & Dauterman, (1996) posited that for most people both visual and analytic thinking may need to be integrated in order to construct rich understandings of mathematical concepts. Yet empirical evidence in South Africa (Sproule, 2005; Bansilal & Naidoo, 2012) and abroad (Zazkis, et al., 1996) shows that learners often have difficulty in making such connections between visual and analytical approaches when solving problems. If this has to be achieved in classrooms, then it is important for us to learn more about how learners integrate the two and how their visual and analytical abilities could be improved. Hoyles and Healy (1997) troubled this integration of visual and analytic thinking in mathematics by posing a question;...

...how can students best be encouraged to share in these ways of thinking – what systems of support can we offer which will encourage them to make connections between visual and symbolic representations of the same mathematical notions (p.67).
To date their question remains an important one, and in this paper I revisit the question by analysing Grade 11 learners’ responses to a task on reflective symmetry with the aim of understanding the extent to which learners integrated their visual and analytic approaches. The specific questions that guided the analysis were:

1. Which of the two, visual and analytic approaches, was preferred by learners?
2. Do the visual or non-visual methods appear to have been used efficiently?
3. To what extent did the learners integrate the visual and analytic approaches?

**Importance of the study**

In South Africa, geometry was central to the debates that shaped current curriculum reforms within which visual and analytical skills are espoused as learners are expected to ‘use spatial skills and properties of shapes and objects to identify, pose and solve problems creatively and critically’ (Department of Education, 2012). In particular transformation geometry is a school subject, which appears to rely heavily upon visual and analytical skills. Like many other areas of mathematics, transformation geometry has also been problematize within the South African education system (Bansilal & Naidoo, 2012) and deliberate attempts are being made to improve learners’ visual and analytic skill levels. Because transformation geometry provides a context for combining algebra and geometry it has been considered by many other researchers (Hoyles & Healy, 1997, Sproule, 2005; Zazkis et al., 1996) as an appropriate conceptual field for assessing learners’ use of visual and analytic skills and abilities. Not only is this ability to imagine and reason about changes of objects and their spatial layout important in transformation geometry but it is also important both for everyday cognition and for reasoning in technical domains.

Literature suggests that visual communication in mathematics education is especially important to students having limited proficiency in English (Cummins, 1984; Dawe, 1983; Presmeg, 1986). Because the First Rand Foundation (FRF) project in our institution, from which this paper draws data, targets learners in previously disadvantaged communities, where language problems have been documented, ensuring learners’ development of their visual abilities is particularly critical for our project.

This paper acknowledges, a similar research by Bansilal and Naidoo (2012), and aims at pushing the visual-analytical agenda further by complimenting these earlier local findings as well as others from the international community. This idea of complimenting research findings follows Harries and Barmby (2006), who argued that all too often, when we assess students’ understanding in mathematics, we are gaining insight into only a small part of this network. We can never have complete understanding; we can always enhance our understanding by developing more links, for example between apparently very different tasks or concepts that we have not associated together previously (Harries & Barmby, 2006). Earlier on Hiebert and Carpenter’s (1992), had proposed that “…understanding usually cannot be inferred from a single response to a single task but a variety of tasks are needed to generate a profile of behavioural evidence” (p.89). Similarly, Vergnaud, (2009) also posited that a concept’s meaning does not come from one situation only but from a variety of situations and that, reciprocally, a situation cannot be analysed with one concept alone, but rather by forming systems from contrasting situations with several concepts. The implication for researchers was that they also needed to carefully analyse the different ways by which children tackle these contrasting situations.
Consistent with this view, in this paper I analyse learner responses to a reflective symmetry task which is significantly different from those that were analysed by Bansilal & Naidoo (2012) but using the same lenses that they also used. In some of my previous work on reflective symmetry, I had provided an analysis of the same task, but through different lenses and the focus was on different levels of concept formation and not how learners integrated visual and analytical skills. Hence the importance of these analyses can also be seen in that they are aimed at providing this ‘profile of behavioural evidence’ thereby adding to our understanding of how learners work with visual and analytic approaches when solving transformation geometry tasks.

Defining visualisation
Because visual and analytical skills are central to this analysis, there is need for the terms to be defined and a position to be taken in terms of how they are going to be used in this paper. According to Zazkis, Dubinsky and Dautermann, (1996):

Visualization is an act in which an individual establishes a strong connection between an internal construct and something to which access is gained through the senses. Such a connection can be made in either of the two directions. An act of visualization may consist of any mental construction of objects or processes that an individual associates with objects or events perceived by her or him as external. Alternatively, an act of visualization may consist of the construction, on some external medium such as paper, chalkboard or computer screen, of objects or events that the individual identifies with object(s) or process(es) in her or his mind (p. 441).

Two views of visualization emerge from this definition, one to do with an external-media-to-mental construction and another one which has to do with a mental-to-external-media construction of a mathematical idea. While Zazkis et al., define visualization this way; their external-media-to-mental view is generally associated with analytical/abstract thinking while the latter view is commonly associated with visualization. According to Kirby and Boulter, (1999), visual is best used to describe the sense modality of vision. Following a similar usage by Presmeg (2006), a visual image is taken to be a mental construct depicted in spatial information. Zazkis et al., (1996), then further elaborate on this definition by pointing to some indicators. For example, an interpretation of the solution of two linear equations in two unknowns as the intersection of two lines in a plane is an act of visualization as soon as the simplest picture (visual) of two intersecting lines is drawn. On the other hand, if a mathematician applied an algorithm to solve two simultaneous liner equations in two unknowns, then by this definition, these would not be acts of visualization. When speaking of such a construction in some external medium, visualization does not need to be accurate – it only needs to be a sketch. Thus in this sense Zazkis et al., link visualization to constructions that transform from mental to an external media and this is the view taken in this paper.

Defining analysis
Zazkis et al., (1996), use the term analysis in a manner similar to the way a biologist analyses the nature of a plant through decomposing it into parts, as well as thinking about the relationships among those parts and synthesizing them into various other wholes such as leaves, flowers and seeds. Thus their view of analysis includes the naming of parts as well as intellectualizing about problems through thinking about relationships among those parts and synthesizing them into various new wholes. According to Zazkis et al., (1996); “An act of analysis or analytic thinking is any mental manipulation of objects or processes with or without the aid of symbols” (p. 442).
These manipulations can generally be viewed as mind-to-mind constructions and include what is usually referred to as logical analysis and reasoning (Dubinsky, 1991). According to Zazkis et al., when the symbols are taken to be markers for mental objects and manipulated entirely in terms of their meaning or according to syntax rules, then that constitutes an act of analysis. With specific reference to transformation geometry, the analytical approach is characterised by algebraic formulae used to describe the results of transformations on figures that are situated within a Cartesian plane. Breen (1997) would see analytical thinking as a tendency towards abstraction and in this paper, an act of analysis is taken as that which involves mainly mental manipulation with the aid of symbols (which could be algebraic or points of the Cartesian plane).

A theory to bring together different visual – analytic perspectives
The need for theory cannot be overemphasised in academic writing as it provides a structured set of lenses through which aspects or parts of a phenomenon can be approached, observed, studied, analysed or interpreted. Numerous theories belonging to the humanities or the social sciences have been employed in mathematics education. These theories differ with respect to many aspects including the way in which claims are derived and justified within the theory. This variability is sufficient to suggest that the notion of theory is not exactly a monolithic one in mathematics education but all the same some theory is needed to provide structure. In deciding on a theory the researcher therefore has to select the elements that are important for consideration in the context.

One of the ways in which theories differ is with respect to whether they come before (top-down) or after (bottom-up) observations are made. In this paper the researcher employed a “bottom-up approach”, where no specific theory was imposed on the data, which were therefore not collected according to a theory-based design – but instead the theory arose from the data through concrete analysis. In deciding on the lenses through which learners’ responses would be analysed, the author considered that the debates around visual and analytic skills in mathematics are presented from different perspectives which needed to be organised into some structure. In this paper Barmby et al., (2007) provided a framework for organising these arguments in terms of internal and external representations of mathematical concepts. Miura (2001) referred to ‘internal’ and ‘external’ representations as ‘cognitive’ and ‘instructional’ respectively. Within this internal-external framework, visualization and analytical skills are presented in terms of (a) how they are internalized by learners (concept formation) (b) how they are taught and assessed by teachers and (c) how they are used or applied by learners during problem solving. I now provide a brief literature review of these three perspectives and show how they shaped the visual-analytic model that became the tool for analysing learner responses.

Visualization as primitive and foundational for concept formation
From a learning or concept formation perspective, visualization is accorded a primitive or foundational status while analysis is considered as indicative of rigour or a form of more advanced reasoning and therefore reflective of a deeper mathematical understanding. Literature suggests that as a learning tool, visual representations of mathematical ideas are especially important at the elementary school level (Stigler et al., 1990) because learners rely more heavily on imagery than do adults (Kossylyn, 1980). With specific reference to transformation geometry, Bansilal and Naidoo, (2012) pointed out that even the van Hiele model of geometric thought specifies visual reasoning level as an initial level of geometric understanding. Breen (1997) also suggested that images provide an important tool for
learning hence visualization would be considered elementary or foundational as it is through imagery that learners gain access to mathematics. It is from this concept formation perspective, that an assumption is sometimes made that learners’ predominant use of visual strategies is indicative of weak mathematical ability (Zazkis, Dubinsky & Dautermann, 1996). The argument was that such learners would still be at the elementary or foundational stage of concept formation hence this paper was also interested to understand which approach learners preferred when solving the task under review.

**Visualization as a form of rigour**
The idea that visualisation is in fact a form of rigour or a higher order skill draws from the mathematical instruction and assessment perspective where deep understanding of concepts can be mediated through external representations (Sierpinska, 1994). The view is that; although a teacher’s or learner’s understanding of concepts is based on mental or internal representations, it has to be externalised in order to be easily accessible either to the learner for concept formation or to the teacher when assessing the presence/absence of such concepts from the learner’s mind. Davis (1984) captures this in the following quote;

> Any mathematical concept, or technique, or strategy – or anything else mathematical that involves either information or some means of processing information – if it is to be present in the mind at all, must be represented in some way (p. 203).

From this view, external representations such as spoken language, written symbols, pictures and physical objects are used in order to communicate (mental) mathematical understanding (Hiebert & Carpenter, 1992). An externalisation of a mathematical concept therefore suggests that an internal representation of that mathematical concept might involve facts about that concept, pictures or procedures that we might draw on in order to explore the concept. So in instruction and assessment what we actually use to access mental images of mathematical concepts are ‘external’ or visual representations of those concepts (Barmby, Harries, Higgins and Suggate, 2007). In examining what understanding is, Nickerson (1985) identified some of its results one of which is envisioning a situation as in a concept map; hence such maps are often used to tease out learners’ understanding of mathematical concepts. By so doing, researchers can view the links that learners make externally enabling us to answer the question ‘does the child have a visual representation for the abstract concept’. This way we can therefore indirectly assess their understanding and also imply gaps that they might have in their understanding of otherwise an inaccessible mental idea (Barmby, Harries, Higgins and Suggate, 2007).

**Visualization and analysis as intertwined in problem solving**
The view that visualization is an integral part of analysis is usually presented not in terms of teaching or learning of mathematical concepts, but more in terms of application or problem solving. For example, a study by Presmeg and Bergsten (1995) on high school students’ preference for visualization in three countries (South Africa, Sweden and Florida in USA) suggested that it was too sweeping a claim that “students are reluctant to visualize in mathematics”. From another study by Stylianou (2001) the results showed prevalent evidence that both experts and novices frequently attempt to use both visual and analytic approaches when solving problems as they perceived visual representation as a useful tool. Both Dreyfus, (1991) and Presmeg’s (1986) work suggested ways in which analysis or logical rationality was intertwined with visualization and their recommendations were that concrete imagery needed to be coupled with rigorous analytical thought processes to be effectively used in mathematics. Kaufmann (1990) also found out that imagery was particularly useful where the
need for processing was high, such as occurs under task-novelty (problem solving) conditions. In such circumstances imagery can provide a backup system that facilitates simpler access to a set of otherwise more complex cognitive processes. Similarly, Pirie and Kieren (1992) suggested that the problem solver goes back and forth from a higher level of processing to a richer visual level when necessary.

However, despite such empirical evidence pointing to this essential companionship between visual and analytic approaches, research has shown that learners cannot connect the two. Observations were that while students are likely to generate visual images, they are unlikely to use them for analytical reasoning (Dreyfus, 1991). Earlier on Presmeg had made similar observations and commented that the most harmful yet quite common difficulty with visualization is that learners have shown a lack of ability to connect a diagram with its symbolic representation (Presmeg, 1986). The call from Presmeg was for mathematics educators to become more knowledgeable about the difficulties and strengths associated with visual and analytical processing by learners. The envisaged benefits were that if teachers had been more explicitly aware of these issues, they would be better able to help the visualizers (weak performers) in their classes to overcome the difficulties by exploiting the strengths thereof. Consistent with this recommendation, the focus of this research was to identify how visual and nonvisual (verbal) approaches might have been integrated by Grade 11 learners as they attempted to solve a transformation geometry task. In my analysis of learner responses I therefore needed a model that could possibly explain how these approaches could be intertwined in problem solving.

The visualization/analysis (VA) model

Zazkis et al., (1996), suggested a model based on discrete levels of visual and analytic thinking which I found useful for analysing learner responses to a reflective symmetry task in this paper. While this model is at best an ‘approximation’ of what is very likely to be a continuum; Zazkis, et al., posit that certain points in this continuum are of particular importance and that it was useful to focus on them in order to describe a generalized development pattern. They further argued that discrete approximations of the continuous were fairly common and very useful in many branches of mathematics and science as they enhance discussions of such continuous phenomena.

So according to Zazkis et al., (1996), whether the event involves motion of physical objects or transformations of mental object, construction of a visualization of it can be described by such a VA model. The VA model can then be seen to describe a series of conversion-type activities between visual and analytic representations, each of which are mutually dependent in problem solving, rather than unrelated opposites. In the model the thinking begins with an act of visualisation, V₁, which could entail the learner drawing some “picture” or some other external means of expressing a collection of mental objects and then constructing mental processes or objects based on this “picture”. The next step is an act of analysis, A₁, which consists of some kind of coordination of the objects and processes constructed in step V₁. This analysis can lead to new constructions. In a subsequent act of visualisation, V₂, the learner returns to the same “picture” used in V₁, but as a result of the analysis in A₁, the picture has now changed.
As the movement between the V and A is repeated, each act of analysis is based on the previous act of visualisation. This act of analysis is used to produce a new richer visualisation which is then subjected to a more sophisticated analysis. This thus creates a spiral effect as illustrated in Figure 1. On a similar note, Siegler, (2003) asserts that a learner’s level of thinking can be viewed as a staircase. Each stair on the upper level represents a new approach to thinking; as you move higher up the staircase, the thinking and approach to a problem become more advanced and sophisticated.

This is particularly evident in reflective symmetry where the thinking about the concept begins with visualization of more familiar everyday phenomena then moving later on to the algebraic rules for describing such transformations. Given this observation; this VA model would then account for at least some of the apparent preference for visualization by the weaker students (Presmeg, 1986) and the proposition thereof that the weaker the student was the less likely he or she was to progress very far. The model could also justify the view that an analytic approach is based on a previous visualization hence the need to coordinate visual and analytic modes of thought as learners can enrich their visualisation with the analytic structure of the task.

The visual-analytic nature of the task
For this paper, I analyzed learner responses to a task given to 235 Grade 11 learners across 23 high schools. The transformation geometry task was in a benchmark test for the First Rand Foundation (FRF) Mathematics Education Chair project. The test was on a wide range of topics and therefore was not aiming at specifically testing visual and analytical skills. However, the task under review required learners to integrate such skills in solving the problem, hence the researcher’s interest in analyzing how the learners responded to the task. The task was as shown in Figure 2.
The questions were phrased as follows:

The diagram above shows a Cartesian plane with points A (-3; 6), B (4; -2) and C (-5; 1).

Draw, on the grid above, A’, B’ and C’, clearly labelling the coordinates of each point if:

(a) A’ is the image of A reflected in the y-axis.

(b) B’ is the image of B reflected in the line y = 0.

(c) C’ is the image of C reflected in the line y = x.

When I examined the characteristics of this task, my view was that the task was significantly different from the ones analysed by Bansilal and Naidoo (2012) in that no shapes were provided but points were physically drawn on a Cartesian plane and coordinates were provided. That way, both the visual approach and analytical approach were equally accessible to learners. In that sense, it was highly likely that the task offered learners an equal opportunity to answer the question from either a visual approach or an analytical approach or by complementing both approaches. Following on this structure of the task one would argue that it had the potential for an increase in the validity of the judgement about the preferred approach.

From a visual approach, I argue that learners could have successfully reflected the given points in the different lines of reflection based on the properties of mirror reflection without resorting to any algebraic formulae. It was also possible for learners to tackle the task from a purely analytical approach by applying algebraic rules for reflective symmetry. The algebraic formulae for reflections are summarised as follows:

Figure 11 Question on reflective symmetry
Table 1

<table>
<thead>
<tr>
<th>Reflection</th>
<th>Algebraic formulae for reflective symmetry</th>
</tr>
</thead>
<tbody>
<tr>
<td>About the x – axis</td>
<td>(x;y) becomes (x; -y)</td>
</tr>
<tr>
<td>About the y – axis</td>
<td>(x;y) becomes (-x; y)</td>
</tr>
<tr>
<td>About y = x</td>
<td>(x;y) becomes (y; x)</td>
</tr>
</tbody>
</table>

In order to successfully use analytic techniques in this task, learners needed to know these rules first and be able to apply the rules using the coordinates of the given points.

In this task, I also argue that learners could have used both the visual and analytical approaches in a complementary role to validate each of their stages of problem solving. For example, a learner might have reflected point A visually in the y-axis, then check that reflection algebraically to validate the image position. This process of moving from the visual to the analytical would have been repeated until all the three points had been reflected in their respective mirror lines. This way, as the movement between the visual and analytic is repeated, each act of analysis is based on the previous act of visualisation. This is what integration of the approaches would entail and is precisely what the VA model suggests, hence in my analyses; I was also interested to see how the learners integrated such approaches.

Results and discussion

From the learners’ responses I observed that the entry point for 85% of the learners was through joining the three points A, B, and C to form a triangle as shown in Figure 3.

![Figure 3 Three points joined to form a triangle](image)

After joining the three points to form a triangle, 43% of the learners then reflected their triangles mainly in the y-axis and in the x-axis. From the way both the definition and properties of reflective symmetry are first presented to learners in elementary grades, I argue that reflective symmetry suggests a visualization of a ‘shape/diagram/figure’ of the ‘same size’ or ‘congruent’ to its image which is ‘reversed’ or ‘flipped over’ or ‘laterally inverted’ in an imaginary line of symmetry. Such imaginary mirror lines are predominantly of a vertical or horizontal orientation as examples are drawn from the everyday experiences of reflective symmetry. This tends to give learners a visual understanding of reflections as the entry point. Consistent with the VA model; the thinking also begins with an act of visualisation, which
could entail the learner drawing some “picture” or some other external means of expressing a collection of mental objects and then constructing mental processes or objects based on this “picture”. Following that process of working with the visual and analytic approaches, the writer argues that the learners’ entry point as they attempted this task was therefore predominantly through visualization as they drew triangles to start with. I however argue that the visualization was not efficiently productive for the learners as the task did not require them to draw a triangle at all hence 45% of the learners were unable to do anything else after joining the three points to form ‘their’ triangle.

I also conjectured that in attempting to solve this task, learners might also have followed a sequential and hierarchical order starting from a visual approach, then complimenting that with an analytical approach. This follows the VA model as well as Franco and Sperry (1977) who also posited that nonverbal visuo-spatial apprehension seemed commonly to precede and support the sequential deductive analysis involved in the solution of geometry problems. In this task, the complimentary role of visual and analytical approaches could also be mapped onto levels of awareness as proposed by Gagatsis and Patronis (1990). These researchers posited that if learners were not so sure of their visual manipulation of the given points, (fragmentary level of awareness) they would fall onto their analytical abilities (partial reorganisation) to re-examine their reflected images. However, from the learner responses it would appear they were still at the fragmentary level of awareness where they were unable to move further to the partial re-organisation stage where algebraic formulae would have been useful as an analytical tool.

Bansilal & Naidoo (2012) carried out a similar study and although part of their results were different in that most learners performed treatments, mainly in the analytic mode when responding to the transformation tasks, part of their observations were also similar to this study in that there was little evidence of movements across or of integrating the two modes. Zazkis, et al., (1996), made similar observations and cautioned that even though both visual and analytical strategies may be available to learners, learners often had difficulty working with the algebraic rules hence they were likely to resist working with such strategies which they find uncomfortable or challenging. Gagatsis and Patronis, (1990) had also noticed that even though learners may know the rules for working out the results of reflections through visual manipulation of the diagram, learners often had difficulty making connections with the analytical rules. Thompson (1985) referred to this inability to see anything in a diagram beyond a static presentation, as figuration-boundness which is described as an inability to go beyond the elements of a problem to a network of relationships and potential transformations in which the elements exist. In this study learners appeared to be unable to make such connections yet such verification ability was not only critical for validating their visual manipulations but that verification/validation is, in its own right, an indispensible life-long mathematical skill.

Besides this inability to work with the algebraic rules, another explanation is also given as to why learners could not fall onto the algebraic rules to verify their reflections. From a visual approach, reflective symmetry can be deceptive in that its properties may appear to be self evident; there is a pre-image shape of the ‘same size’ or ‘congruent’ to the image which is ‘reversed’ or ‘flipped over’ or ‘laterally inverted’. This deceptive nature of mathematics is common in many areas and was also observed particularly in reflective symmetry by Hoyles and Healy (1997) where learners in their study were resistant to checking their constructions by some other methods because their images ‘looked like a reflection’. There was nothing to
suggest otherwise hence they saw no reason to check or verify. These findings are evident in the learner responses that I analyse in this paper as all the learners seemed to think about reflection as flipping over the horizontal or vertical axes. They also tried to draw the image congruent to their incorrect pre-image without attending to the required lines of reflection and without using other methods like the algebraic rules to verify or check the accuracy of their constructions presumably because their constructions ‘looked like reflections’.

**Conclusion**

The first question in this paper concerned the preferred approach to solving the reflective symmetry task. The analyses revealed that the predominant approach to solving the reflective symmetry task was the visual approach. Learners visualised a shape (triangle) which had to be reflected in the y or x- axes instead of three independent points located on the Cartesian plane. The second concern was with whether or not the learners used the approach efficiently. The observation was that while a strong visual sense of reflection clearly played a central role in the learners’ approaches; it was not used efficiently as most learners visualized a triangle which was not implied in the task hence they were unable to go any further in solving the task. Finally, the paper raised a question on whether there were any signs of integrating the two approaches which was critical for validating their solutions. The observations were that there were no signs of integrating the approaches in the learners’ responses. So unless visualization was coupled with an appropriate symbolic/analytical counterpart, learners were unlikely to build reflections in a consistent way which connects visual intuitions with mathematical structure. This underlines the problem with an approach to teaching which stresses visual appreciation disconnected from formalisation.

**References**


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How did pupils solve number brick after lessons of substantial learning environment in Central Province, Zambia?

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This article qualitatively discusses the characteristics and difficulties that three pupils showed during solving number brick after mathematics lessons at the basic level in the Republic of Zambia. Number brick is part of Substantial Learning Environment (SLE) which is teaching unit. The analysis of the interviews by pupils identified four learning characteristics observed in these three students’ activities: recognising and discovering number sequences and rules, the mixed method of calculations; instability of learning, and the way of expressions. They were also negatively and positively related to teaching in class.

Background and research question

In Zambia, pupils’ low performance is a critical issue in the education sector with lack of teaching materials and teachers’ competencies (Examination Councils of Zambia: ECZ, 2008). ECZ(2008) suggested comprehensive remedial measures, for instance, ‘use varying teaching approaches’, and ‘encourage teachers to use visual aids when teaching Numeracy’ (ECZ, 2008, p.105). However, there are not academic debates on what teaching and learning is like and on how it can be improved in mathematics classroom.

Many internal and external factors influence teaching and learning in class, so its process is unquestionably complicated. Some studies have developed models of the structure of lessons (e.g. Huber, 1972; Hioki, 1990; Akita, 2006). Didactical triangle (Huber, 1972) could be one of the classic models to be well-known. It shows the interactions of teacher, pupils and teaching/learning material (Fig. 1).

![Didactical triangle](image)

(Huber, 1972)

**Figure. 1** Didactical triangle

The study applied SLE as teaching/learning material into Zambian mathematics classroom to improve the quality of lessons as well as to reveal the interactions of the three factors in the didactical triangle. Therefore, the research question of this study is to examine the effectiveness of SLE to teaching and learning in the Zambian context. The article specifically pays attention to discussing pupils’ learning characteristics in solving one of SLEs, called number brick, and touches upon the teaching in class partly because teaching and learning cannot be separated. The aim of the paper is to analyses individual pupils’ learning process in the activities of number brick after lessons of SLE and to discuss their learning characteristics and difficulties.
**What is SLE?**

According to Wittmann (1995; 2001), SLE can be placed in the conceptual framework to understand mathematics education as well as be interpreted as set of teaching/learning materials. SLE was developed in a project called *mathe 2000*. The project regards mathematics education as *design science* (Simon, 1969), also mathematics as *the pattern of science* (Deblin, 1995; Steen 2000). In the project, three areas of research and development are interrelated to each other and pursued simultaneously: the design of SLEs and curricula; empirical studies into children's thinking and communication in the classroom; and practical work, for instance, pre-service and in-service teacher education in both mathematics and didactics, school development, counselling (mathe 2000 homepage). Wittmann(1995) placed the development of SLE in one of the cores of mathematics education and claimed that SLE can bridge the gap between theory and practice as shown in Fig. 2.

![Systemic relationship between theory and practice](image)

(Wittmann, 2001, p.5)

**Figure 2. Systemic relationship between theory and practice**

Wittmann(2001) showed the four characteristics of SLE as follows instead of defining it explicitly:

1. It represents central objectives, contents and principles of teaching mathematics at a certain level.
2. It is related to significant mathematical contents, procedures and processes beyond this level, and is a rich source of mathematical activities.
3. It is flexible and can be adapted to the special conditions of a classroom.
4. It integrates mathematical, psychological, and pedagogical aspects of teaching mathematics, and so it forms a rich field for empirical research.

(Wittmann, 2001, pp.365-366)

Wittmann(2005) explains that SLE is for the basic level of mathematics; however, it can be advanced above a certain level in (1) and (2). In practice, Wittmann and Müller(2000) developed many SLEs such as *Zahlenmauern* (number wall; number brick), *Rechendreieck* (calculation triangle) and *Schöne Päckchen* (beautiful package). Wittmann(2004) intends the two objectives for mathematics learning: *inhaltliche Lernziele* (content-related objective) and *allgemeine Lernziele* (general learning objective) concrete objectives and general objectives). He claims that learning in SLE will achieve the two objectives which are for
basic knowledge and skills and applied skills such as reasoning, investigating, communicating, mathematizing.

**What is number brick?**
Number brick (Wittmann and Müller, 2000) is one of the most well-known SLEs for addition and subtraction. The basic rule is ‘to write the sum of the two adjacent numbers on the above brick’ shown in Fig. 3.

![Figure 3](image1.png)

**Figure.3 Example of number brick(1)**

It can be used for mastering calculation for the lower grades as well as for discovering number patterns and investigating more mathematical rules. In the German textbooks written by Wittmann and Müller (2000), pupils are to learn number brick from grade 1 to grade 4. They can choose what operation should be applied to fill in the blanks. After the calculation, they are expected to investigate the structure of number brick, for instance, to find number sequences or relationship between numbers for further mathematical communications in class. In Fig. 4, for instance, after filling in all the blanks, pupils may say, ‘The numbers on top are changing 100, 90, 80, 70. The rule is subtracting by 10’, ‘The numbers on the left bottom are changing 2, 4, 6, 8. The rule is adding by 2’, or ‘The fourth blank will be …’ for further investigations of number brick.

Calculate number bricks and discuss some patterns that you can observe.

![Figure 4](image2.png)

**(Nakawa, 2012)**
**Figure.4 Example of number brick(2)**

**Application of SLE to Zambian context**
In Zambia, literacy and numeracy, mathematical knowledge and skills, communication and problem solving skills are emphasized to foster in a child as learning outcomes in mathematics education (MoE, 1996; CDC, 2003). However, they are not successfully achieved in classroom (Shibuya, 2008). In correspondence with these outcomes, SLE can be introduced in Zambian classroom because it intends to promote both basic computation skills and applied skills. For the introduction, it should be restructured for the Zambian context,
because SLE was modified and applied in different countries such as Japan (e.g. Yamamoto, 2008; Miyawaki, 2009).

In this study, at first, the efficacy was examined various SLEs in JETS (Junior Engineers, Technicians and Scientists) club in Zambia in 2008 (See Shibuya, 2008) and selected more effective SLEs based on the observation of the practice. Number brick was one of the selections. In the lessons, we kept modifying it according to pupils’ learning continuously throughout lessons. Before lessons, the goals were determined in relation to the two objectives Wittmann (2004) stated shown in Table. 1.

Table. 1 Objectives of number brick activities

<table>
<thead>
<tr>
<th>Content-related objective</th>
<th>To be able to operate following the basic rule of number brick</th>
<th>To be able to calculate addition and subtraction correctly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reasoning</td>
<td>To be able to reason the next number by looking at the number sequences in the structure.</td>
<td></td>
</tr>
<tr>
<td>Investigating</td>
<td>To be able to create the next brick by looking at the number sequences in the structure.</td>
<td>To investigate number patterns in the structure.</td>
</tr>
<tr>
<td>Communicating</td>
<td>To express pupils’ mathematical ideas and thinking by languages, gestures, and in sentences</td>
<td></td>
</tr>
<tr>
<td>Mathematizing</td>
<td>To generalize the rule of number sequences</td>
<td></td>
</tr>
</tbody>
</table>

Methodology
In each activity of planning, implantation and evaluation in the whole lessons within the action research cycle, the interactions were examined through conversations between teacher and the author, and teacher and pupils in class and their behaviours. From the constructive point of view, the author examined how they understood SLE treated in class and created their own mathematics in their activities after mathematics lessons by interviews and identified their difficulties and development for these skills mentioned (See details in Nakawa, 2012). This article discusses the analysis of three pupils after each lesson. Three pupils with different academic performances in a grade 5 class were selected for the in-depth interviews. After each lesson, the pupils solved a few tasks (see Appendix), related to the contents they learned in class six times. Their names were Vivien, George and Paul, with academically below-average, average, over-average respectively. Vivien had much difficulty in talking in English, and the other two were better speakers than she. Qualitative and quantitative analysis are employed to understand pupils’ and teachers’ changes on teaching and learning in order to explain the complex phenomena in/after lesson.

In the part of the study, two mathematics periods per day were taught in Kabwe, Central Province from May to June 2009. Firstly, the recorded interviews were transcribed, and their ways to answer questions were inductively classified as ‘talking’, ‘writing’ and ‘non-verbal expressions’ including gestures. Secondly, the pupils’ performance in the interviews was interpreted semantically in order to determine commonalities of their learning.

(1) Case of Vivien, a below-average pupil
Vivien, below-average learner, took much time to finish filling in number bricks by calculation followed by the basic rule of number brick in Fig. 5.
In Fig. 5, Vivien was planning to write 53-29 on the left bottom number brick, but she wrote 3+9. After the author confirmed the way she calculated for number brick, she solved in the middle brick in Fig. 5.

S (Write 53 and 29 in number bricks, and write 2).
T Which operation did you use?
S 9… add 3 (showing that 9+3)
T But this plus this, this one. Apa(here) plus apa… this one. Showing an example to make sure if she understood how to operate on number brick.

T What about this? Are you adding this (29) and this (53)?
S Yes
T Umm, but this and this, next to each other (Showing the numbers) This(29) plus this(blank) becomes 53.
S (Silence)
T Okay, let's do this. (showing the second question, the middle one in Figure 1)
S (Comparing 79 and 28, and write 51 on the right bottom)
T You put…how?
S (Pointing to 79 and 28) Subtraction. (She was thinking, looking at 35 and 28)
T You can write the counting
S (Writing up sticks, 7, and rewrite 27.)
T But 27 is smaller than 28?
S (Rewrite 35)
T How did you get this? Which calculation?
S (Pointing out numbers.)
T The rule is…(Explaining the basic rule of number brick)
S (Wrote 21eventually)
T Lemba (Write)
S (Seems to go back to the first questions, but she did not fill in the number on top in the second question)
T What about this one? How do you get this?
S (Write 58.)
T You are not adding 1+9?
S (Rewrite 10, and 21+79=90 (wrong answer))

(Post-interview in the 2nd lesson, T: interviewer, S: pupil)

She did not calculate using the rule, when the questions became more difficult than the previous ones. When she got stuck, the author confirmed the rule of calculations. She slowly seemed to understand the procedure. In the end, however, she sometimes used addition toward the one for subtraction wrongly.
Example of subtraction  Sticks for calculation by her

Figure 6. Vivien’s calculation

In Fig. 6, 30-20=□ or □+ 20=30 are typical strategies to think of, but Vivien counted one by one with fingers and verbally in order to obtain how many number should be added to 20 in order to reach 30. In calculations with 3-digit numbers, she sometimes used vertical calculations. Overall, in her solving process, she fairly counts by fingers and sticks, rather than to calculate using vertical calculations.

She slowly got used to some activities. After the 3rd lesson, she started to monitor the number patterns and filled in the blanks shown in Fig. 7. She did not say the rule of number sequences and answered ‘2’ instead of saying ‘adding 2’, shown in the transcription below.

Figure 7 Activities for number bricks (3rd lesson)

T  What is the rule?
S  The rule is 2
T  What is 2?
S  2…
S  It is 4.
T  No, addition, subtraction, multiplication, division.
S  Ah- add
T  Add?
S  Add 2
T  Can you write here?
S  (Write ‘Add 2’)

(Post-interview after the 3rd lesson)

She confirmed the number sequences verbally from the 4th lesson to the 6th lesson. After the introduction of the format (Fig. 8) in the 7th lesson, she answered the number sequence, and then, she reached writing up the rule of number sequences in Fig. 9.
Figure. 8 The format for a number sequence and its rule introduced by teacher in class

(Post-interview after the 6th and 7th lesson)

Figure. 9 Vivien’s writing the rule of number sequence

Furthermore, she explained the reason why only six number bricks can be fit with 7, 8 and 9 on the lowest bricks as below.

T Which one is the pair to this? Landa chibemba (Speak in Beemba). My question is ‘why can we know there are only 6?’, ‘Why not 7?’, ‘Why 5, why not 5. Why not 7?’
S …had 8, 7, 9.. Then…
T Can you say it again? Can you speak a bit. Speak up! Chibemba kulemba, landa. My question is… why can you get only 6? Not 6, not 7, not 8 but why are you saying there are only 6?
S Ma numbers are here. (Pointing to 8)
T These? 8?
S Yes (Pointing to the pair of 8 focusing on the numbers on the left-bottom)
T And then 7?
S 7
T Apa?
S These (Pointing to the pair of 7) 8 and 9. (She was making three pairs of number bricks, looking at the middle bottom numbers. And she showed there were only 6 bricks)
T Aha- you are perfect. Thank you very much.

She made a circle on the numbers and explained by action. This shows that Vivien attempted to reason and explain her ideas in some ways: pointing out and speaking. On the other hand, she recognized the wrong number sequences as the appropriate arithmetic progression, for instance,’49, 46, 43, 36’. She found number sequences and described the rule of number patterns although she included incorrect sequences and did not check if they were correct. (2)
**Case of George, an academically average pupil**

George solved questions differently from Vivien in the activities. He followed the rule of number bricks. In most cases, he did mental calculations as well as using fingers and murmured counting. Nevertheless, it did not mean that he was not able to calculate vertically. With 2-digit numbers, he switched to adjust vertically. In the mental calculations of 2-digit numbers, he followed the same way, starting from ones. When he realised mistakes, he adjusted the number slightly, which was not observed in Vivien’s activities. He recognized the change of number arrangements after the 3rd lesson, reasoned the size of numbers, noticed his mistakes, and corrected the wrong answers. Instead of calculating vertically, he either counted with fingers and sticks or did mental calculations. He also reached the stage where he successively described number sequences and rules in parallel with teaching and learning in class.

**(3) Case of Paul, over-average pupil**

Paul followed the rule of number brick easily shown in Fig.10. Paul used vertical calculations to most of the questions, even so for 1-digit number in Fig.11. He occasionally counted by fingers or verbally using verbal calculations. Regarding number sequences, he found number sequences and wrote their rules. At first, he did not write more than a few number sequences, and he became to write as many number sequences as possible. He reached the point where he was open to create multiple discoveries in the structure of number bricks.

![Figure. 10 Paul’s activities after 4th lesson](image)

![Figure. 11 Vertical calculations by Paul](image)

The results of three-pupils’ interviews reveal that Paul’s calculations were more appropriate than George’s and Vivien’s. Paul also calculated vertically more often than them. All of them, therefore, showed some improvement for writing up number sequences with the rule; however the extent of improvement depends on individual learners. The number sequences embedded in number brick were unsophisticated, such as ‘2, 4, 6, 8’, or ‘20, 15, 10, 5’. However, since grade 9 pupils in Zambia had some difficulties in number bricks (Shibuya, 2009), the teaching had a positive impact on pupils’ learning.
**Mixed method of calculations**

The mixed method of calculations means the eclectic way of calculations with vertical calculations and fingers/sticks counting. Fig. 12 shows the three pupils’ approaches in calculations. Mental calculations, use of sticks and/or fingers, mental calculations in vertical format and vertical calculations were observed.

![Figure 12](image)

**Figure. 12** Frequency of three pupils’ ways of calculations during interviews

Only Paul calculated vertically, and the other two were more likely either to do mental calculations or to count. The syllabus (CDC, 2003) states that grade 5 pupils are expected to carry the abstractly presented vertical calculation. They begin to learn calculations starting from grade 1. However, it seems that mastery of 1-digit numbers’ addition or subtraction such as 8+7 or 7+9 was not completed in the lower grade and that they got used to the eclectic calculation. George and Vivien know how to deal with vertical calculations; however, they preferred to count with fingers or to do mental arithmetic. Only in case they feel that these numbers are large enough for them to count they switch to vertical calculation. It indicates that pupils were not able to make a validate choice in selecting approaches, except that they improved to answer correctly in calculations. This would be caused by the syllabus and contents of textbooks, including teaching. In learning calculations, sets of 10 are emphasized in textbooks; however, there are just sequences of addition for routine practice without learners understanding the meaning of operations. Also, vertical calculation starts with the calculation of 1-digit numbers in grade 1. The importance and usability of vertical calculations does not seem to be mentioned. Most of the Zambian teachers use textbooks in class, compared with other teaching and learning materials, the purpose of using the vertical approach would not be well-explained in class. Consequently, the way how pupils have learned calculations would have influenced pupils’ solving approaches.

**Instability of learning**

Instability of learning includes the following two conditions. The first regard is pupils’ confusion due to lack of flexibility in different questions. For instance, when blanks are in more complex places in which they need to think of the order of calculations, Vivien went into chaos and could not calculate correctly in a chaotic state. Depending upon the difficulty of questions, the procedures and things that pupils already used became in doubt. She went into this situation more often than the other two.

The following regard is the confusion in the process of calculations. For instance, they said that they were doing addition; however, they were subtracting. Also, they intended to place a
number on the appropriate position, but they put the number in a wrong place. These inconsistent mistakes occurred in Vivien’s work more often than the other two. This could be partly due to pupils’ carelessness, and due to lack of their reflections during mathematical activities.

In addition, teaching sometimes influenced pupils’ instability in a negative sense. Teacher occasionally inclined to tell pupils only algorithm or procedure without the reason why, and pupils ended up with memorising the algorithm. Consequently, instability is caused by both pupils’ absence of reflections and teacher’s pedagogy in class.

Characteristic related to language

Fig. 13 shows the classifications of verbal responses by pupils. Firstly, ‘murmuring and counting’ is the most common during calculations. ‘Unclear explanations’ is found to be the response toward ‘Why did you think so?’. In such a question, pupils were not able to say the reason clearly, and they rather stated the procedure and the order of the calculations.

Secondly, ‘explanation of number sequences and their rules’ indicates that they were more or less engaged in these activities. It shows that the purpose of lessons was seen in pupils’ learning. This result would provide us with a positive clue: teacher could mitigate pupils’ language difficulties by introducing a language format or support for more advanced mathematical explanations. Teaching was, to some extent, valid for three children, even though they had a language difficulty in English. They showed a variety of communicative ways such as writing and verbal expressions.

![Figure 13. Classifications on ‘speaking’ in the pupils’ activities](image)

**Conclusion**

The characteristics of learners were recognising and discovering number sequences and discovery of number, mixed method of calculations, instability, characteristic related to language. Regarding number sequences, the language format introduced by teacher influenced pupils’ learning. The three pupils successively wrote number sequences and their rules, which was a different result from grade 9 (Shibuya, 2009).

Difficulties of questions, teacher’s pedagogy and pupils’ lack of reflection influenced their instability of learning. The author suggests that teacher and the author should have designed more detailed lesson plans including how teacher should raise questions and explain to them.
in class. Moreover, if teacher intends to prepare advanced questions for higher-order thinking, s/he should watch where pupils stumble and engage in remedial supports. The three pupils can make use of vertical calculations, but they are substantially counting, which could be said that their mathematical level stays relatively lower than expected learning in syllabus. This implies that there is a significant gap between teaching calculation in class and pupils’ strategies. In this regard, teaching did not change pupils’ ways of calculations. Considering that grader 5 pupils already learned the form of vertical calculation a few years ago, it seemed impossible to change their ways without coming back to the meaning of vertical calculations.

Taking a glimpse of the individual learner’s achievement in table 1, George and Paul calculated accurately using their acquired method; however, the quality of their skills did not change except for the development of getting correct answers. Vivien showed an immediate improvement on calculation itself, which was probably because her mathematical ability was extremely lower at the beginning. Therefore, SLE could offer less-skilled pupils a reasonable opportunity of calculation practices; on the other hand, it was not particularly useful for those who mastered calculation in their ways. SLE would have been more effective if we had introduced it to the lower grades such as grade 2 or 3 in which pupils learn the structure of calculations in the earlier stage of mathematics.

Related to general learning objective in Table.1, the pupils succeeded creating new number bricks by looking at the pattern of numbers through reasoning and investigating. Despite of English difficulty, they reached the point of writing number sequences, and succeeded answering some questions on number sequences. George and Paul noticed the change of numbers and wrote its rules. Vivien occasionally made a wrong judge on number sequences but showed a remarkably enthusiastic attitude of expressing her idea verbally and nonverbally including gestures. The two pupils with average and over-average performance improved mathematically higher-order thinking skills such as reasoning, investigating, communicating and mathematizing, and one less-average pupil showed some improvement. Thus, the feature of SLE positively impacted pupils’ learning. It indicates that modified SLE can be an outstanding teaching and learning material in Zambia with the language support. The language format is not used in the original SLE. It can be a scaffold for Zambian pupils but, at the same time, it could be dangerous to continue using it because it may hinder pupils’ free ideas.

Consequently, the paper analysed three pupils’ interviews and discussed their mathematical development and challenges with their characteristics. As a result, the author identified the four characteristics that learners showed. Their learning gradually improved accordingly to the contents of teaching in class, which was different from the discussion in Shibuya(2009). However, challenges also remained. The author would like to link the result here and the whole-class teaching and learning happened in class.

References


Appendix: Worksheets

Interview after the 1

st

lesson: Complete number bricks. Show your work.

Interview after the 2

nd

lesson: Complete number bricks. Show your work.

Interview after the 3

rd

lesson: Complete number bricks. Show your work.

4. Using cards of 8,7,9 at the bottom of number brick, make as many number bricks as possible:

Interview after the 5

th

lesson: Calculate number bricks and find number patterns.

Interview after the 6

th

lesson: Complete number bricks and find number patterns.

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On the constituents of Primary Maths Teacher Identity: Towards a model.

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Abstract

This paper discusses key constituents in developing a model of Primary Maths Teacher Identity. In enlisting the core aggregates of Primary Maths Teacher Identity this paper is informed by the literature on maths teacher identity, situative-identity theories (Lave & Wenger, 1991; Wenger, 1998) and Bernstein’s (1975; 2000) sociological theory. Empirically the paper draws on data obtained from interactive interviews with 10 sampled primary maths teachers who were participants in a numeracy community of a practice-informed teacher professional development programme called NICLE. The research indicates that subject specialisation, phase specialisation, reform education policies, teacher education, school context, life maths experiences and school maths learning experiences, constitute the main components of Primary Maths Teacher Identities.

Introduction

In this paper we discuss key constituents of Primary Maths Teacher Identity, hereafter referred to as PMTI. The aim of this paper is to formulate the parameters of PMTI. In delineating the constitution of PMTI this paper is illuminated by the literature on maths teacher identity. The study identifies; subject specialisation, phase specialisation, pre-service training, national educational/curriculum policies and reforms, the school context, engagement in maths professional development programmes, further maths education training, school maths learning and maths life experiences as the critical factors that shapes the notion of primary maths teacher identity. Some of these elements had already been identified in the literature as contributing to teacher identity. The tentative model developed in this paper reflects the relationship between the above mentioned factors and the core element and notion of PMTI. Though we have tried to consider all the elements that can be factored in the notion of PMTI we believe that any teacher could add any components that s/he could consider key to this concept based on their particular localised history and trajectory. Thus we leave in our model an unmarked space to allow readers, maths education researchers and primary maths teachers themselves to add any component beside those mentioned in this model.

In making our proposition and arguments we draw from the empirical data from our study site which is a primary teachers’ mathematics professional development initiative called the Numeracy Inquiry Community of Leader Educators (NICLE). The numeracy professional development programme was conceptualised by the second author who holds the South African Numeracy Chair at Rhodes University in Grahamstown, in the Eastern Cape Province. The numeracy professional development programme has been explicitly designed as both a Community of Practice (Wenger, 1998) and a Community of Inquiry (Jaworski, 2005) teacher development approach. NICLE focuses on the foundation and intermediate phases in 15 primary schools in the greater Grahamstown area and has 57 teachers who attend fortnightly seminars and inquiry sessions. The data presented in this paper is from interactive interviews with 10 sampled teachers who are part of a broader doctoral research

184
study of the first author. We sampled teachers who actively participated in and frequently attended NICLE sessions.

In mapping a tentative model of PMTI we highlight the importance of paying attention to teachers’ views and to their ‘voices’ as captured in the interactive interviews. One of the reasons for doing so is that this paper implicitly draws from the post-structuralists’ notion of foregrounding the participants’ views or voices in the study. Also central to our model proposition and influencing our ultimate perception of PMTI is the theoretical framework. Any study on the concept of maths teacher identity is influenced by its theoretical positioning as this implicitly indicates one’s research preferences. Several studies in outlining the notion of maths teacher identity bear the influence of their respective theoretical framing (e.g. Davis et al 2007; Graven, 2005; Parker, 2006; Morgan et al, 2002; Lerman, 2012a; Lasky, 2005). This study is theoretically informed by the participation perspective (Sfard, 1999) especially the situative-identity theories (Wenger, 1998; Lave and Wenger, 1997) and sociological theories (Bernstein, 1975, 2000) which are both informed by modern social theory. Also influencing our model of PMTI is the literature on teacher identity, maths teacher identity and specifically that on primary maths teacher identity. This we argue is essential in enlisting the components of PMTI. The literature survey helps us to configure our construct of PMTI as we become more aware of the key aspects of identity that have been raised and discussed by other researchers. Our literature informed development of this model enables us to explain what PMTI is and what it is not? Thus our study informed by the three critical elements of; teachers’ voices, maths teacher identity literature and the situative socio-cultural theoretical framework investigates what PMTI is?

**Literature review**

We engage with both the local and international literature to discuss the notion of maths teacher identity, which is proving to be increasingly popular in many mathematics education research studies. There have been studies on maths teacher identities within education reform contexts (Morgan et al, 2002; Lasky, 2005; Walls, 2008; Parker, 2006; Graven, 2003), mathematics teacher identity formation during professional development (Davis et al, 2007; Graven, 2005; Drake et al, 2001; Van Zoest & Bohl, 2005), in pre-service maths teacher education programmes (Parker, 2006; Marsh, 2002; Ensor, 2001) and in further maths education training (Hodgen & Askew, 2007; Lerman, 2012a & 2012b). There have also been studies that have investigated how teacher identity is influenced by subject specialisation (Jansen, 2001; Bernstein, 1975; 2000), phase specialisation (Pausigere & Graven, 2012), school contexts experiences (Clandinin & Connelly, 2006; Marsh, 2002; Ensor, 2001), school maths learning experiences (Lerman, 2012b; Hodgen & Askew 2007), and life maths experiences (Marsh, 2002; Askew et al). Bernstein (1975; 2000), Jansen (2001) and Clandinin and Connelly’s (2006) teacher identity influencing factors are also applicable to maths teacher identity.

Of the above cited examples on maths teacher identity most dealt with maths secondary school teacher identities (Morgan et al, 2002; Lasky, 2005; Graven, 2005; Parker, 2006; Van Zoest & Bohl, 2005), some investigated both primary and secondary schools’ maths teacher identities (Davis et al, 2007). Drake et al’s (2001) study focused on primary teachers’ maths and literacy identities. A few studies have focused on primary maths teacher identity and these have been either within in-service programmes or during education reforms (Graven, 2005; Hodgen & Askew, 2007; Wall, 2008). However we have not found published studies investigating the constituents of PMTI and relating this construct to the literature, the teachers’ voice and the theoretical framework. Thus a study on the aggregates of primary
maths teachers’ identity would contribute to this identified gap in the literature and also to the growing body of literature that investigates maths teacher identity.

Most studies on maths teacher identities have been theoretically informed by Lave and Wenger’s situated theory (Graven, 2003 & 2005; Lasky, 2005; Hodgen & Askew, 2007; Van Zoest & Bohl, 2008), the post-structuralists (Walls, 2008; Lerman, 2012a) or Bernstein’s sociological theory (Davis et al, 2007, Morgan et al, 2002, Parker, 2006) to understands maths teacher identity formation. This study uniquely comes from a different theoretical dimension and is informed by both notions of Wenger’s sitative theory and Bernstein’s sociological theory yet implicitly draws from the post-structuralists’ notion of foregrounding the participants’ views or voices in the study.

**Theoretical framework**

This paper is theoretically informed by the situative-participationists framework especially Wenger’s notion of identity. Under the situative perspective, learning within Communities of Practice is a simultaneous process transforming knowledge and constructing identities of participation (Wenger, 1998; Lave and Wenger, 1991). Borrowing from this theoretical position we want to argue that primary teachers’ participation in numeracy teacher professional learning communities such as NICLE, transforms their knowledge and construct mathematical identities of participation (Wenger, 1998; Lave & Wenger, 1991). Also to help us understand the process of primary maths teacher identity formation and learning will be ‘engagement’, which is one of Wenger’s three modes of belonging, namely alignment, engagement and imagination. I will use the aspect of engagement to relate to how primary maths teachers in NICLE engage with practices and identities promoted in NICLE and how this shapes their maths identities. Wenger’s (1998) characterisation of identity as a ‘nexus of multimembership’ will illuminate the specialisation element which is one of the key constituents of primary maths teacher identities.

We will complement the sociocultural construct of identity with Bernstein’s (2000) model of pedagogic identities which helps us to investigate primary maths teacher identities within educational reform contexts. Wenger and Bernstein’s work coheres as both writers borrow from the modern version of the social theory and connect their work to theories of power and theories of identity (Wenger, 1998, Sadovnik, 1995). Similar to the two theories is how they define identity with Wenger (1998, p. 5) defining identity as ‘a way of talking about how learning changes who we are’, Bernstein defines identity as ‘what I am, where, with whom and when’ (Bernstein & Solomon, 1999, p. 272). Informed by our theories we provide a working definition of PMTI as a way of talking about who primary maths teachers are? The theoretical orientations and elements discussed herein will assist us to delineate some of the constituents of the PMTI model, thus aiding our investigation of what PMTI entails?

**Research methodology**

Whilst the PhD study of the first author uses the ethnographic approach to study primary maths teachers identity formation through participation in NICLE, this paper reports from data obtained through interactive interviews with ten sampled primary teachers. The interactive interviews were carried out in November and December 2011, with ten purposively selected primary maths teachers participating in NICLE. We selected teachers who actively participated in and frequently attended NICLE sessions and additionally these teachers were willing to be part of the longitudinal research study. A semi-structured interview schedule with open-ended questions was used to gather the data presented in this
paper. The average time for each interview was 1hr. All interviews were conducted at the respondent’s school and were audio-recorded and fully transcribed. In this paper we report on the key emergent themes in the teachers’ interviews to empirically support our PMTI. Foregrounding the experiences and the voices of the teachers is also key in delineating what PMTI consists of.

Teachers in the sample are from four different types of schools in the South Africa education system. The digit besides the teachers’ pseudonym indicates the grade(s) taught by that teacher. Four teachers are from a farm school which had multi-grade classes (Mary 0, Belinda 1, Swallow 2/3, Everton 4/5), two are from a historically African township school (Pamela 3 and Calvin 6), two are from historically Coloured schools in a historically coloured area (Edna 0 and Robert 4-7, the latter only taught maths classes at his school) and two are from an ex model C preparatory school in a formerly white area (Melania 3 and Ruth 3). In this sample of teachers three are intermediate phase teachers, two of these are male (Calvin and Robert) and only taught maths classes at their respective schools. The other female intermediate phase educator was an all-subjects multigrade teacher (Everton). The other seven teachers in the sample are all female foundation phase teachers; two of these are grade R teachers (Edna and Mary). It is important to note that all the foundation phase teachers participating in NICLE were female.

**Discussion: Towards a model of primary maths teacher identity.**
We begin our discussion of what constitutes or are the core components of PMTI in the light of teacher identity literature and the data that we have gathered in the interviews.

**Subject specialisation**
Generally one’s subject (matter) specialisation/competence is a key aspect of one’s teacher identity. Bernstein (2000, p. 212) has argued that ‘it is the subject which becomes the lynch pin of the identity’. Concurring with this assertion, locally Jansen (2001) posited that one’s ‘subject matter competence levels’ is the professional basis for teacher identity. In our study sample two male teachers teaching in the intermediate phase Calvin and Robert were maths subject specialists and had been assigned to teach only maths in their respective schools. For both teachers their maths specialisation had taken place during further maths education training when both enrolled for Bachelor degrees in Maths Education at Rhodes University which had an intermediate phase maths specialisation component. These teachers were quite assertive of their mathematical identity as Calvin said, ‘You know, I like teaching Maths. In fact I, I, wouldn’t like to teach another subject’. Similarly Robert’s teaching identity was firmly entrenched in maths to the extent that he claimed to be ‘…. an authority in the intermediate phase mathematics’. Intermediate phase teachers who only teach maths at the primary level can thus embrace strong mathematics specialisation identities as indicated by Bernstein (2000) and Jansen (2001).

**Phase specialisation**
This study involves 7 foundation phase numeracy educators who unlike Intermediate, Senior or FET phase teachers do not have mathematics subject specialisation as an influential indicator of their identity. In our earlier work we discuss how Foundation phase teachers in addition to numeracy also teach Literacy and Life skills and thus from a subject specialisation perspective their professional teacher identity is fragmented (Pausigere & Graven, 2012). In other words Foundation phase teachers have multiple identities when we factor in their teaching subject specialisation. All the foundation phase teachers, firmly and uniformly
asserted that they were not only numeracy teachers. Numeracy teaching was only a part of their teaching. Belinda said, ‘we teach numeracy, literacy and life skills, I don’t really see myself as a numeracy teacher’. Melania had also said the same thing,

‘I wouldn’t like to see myself as only a maths teacher...In foundation phase you got to teach everything....you know the three Rs, reading, writing, arithematics and everything else in-between’.

This resonates with what Everton, Swallow and Pamela had said. Ruth succinctly captured her multimembership when she said,

‘we are mixed teachers...we teach all the subjects.....we are not really specialist numeracy teachers...so you teach numeracy in the morning and then there is literacy, there is life skills, there is art, there is PHYS ed, there is, whatever there is....’

The sampled foundation phase teachers participating in NICLE thus embedded their numeracy teacher identity within their foundation phase teaching across subjects (Pausigere & Graven, 2012). Bernstein (1975) has also acknowledged that ‘infant school teachers are not socialised into strong educational identities’. To understand the Foundation phase identity of the sampled participants we employ Wenger’s (1998) characterisation of identity as multimembership which shows that ‘membership in any community of practice is only a part of our identity’ (Wenger, 1998, p. 158). Though they had participated in NICLE their teacher identity was not subject-specific but a nexus of multimembership in which it was both one and multiple (Wenger, 1998). Such a multi-membership teacher identity would be attributed either to the phase taught or phase specialisation under which one was trained.

**Pre-service training**

Literature on pre-service maths teacher education programmes has discussed how both secondary (Ensor, 2001; Parker, 2006) and primary (Marsh, 2002) maths teacher identities are fashioned through initial teacher education training. In our sample, Belinda indicated in the interview that her mathematical understanding and practices had been influenced by her initial training as a Montessori teacher. Belinda was orientated to the Montessori, ‘holistic child approach’ that emphasise practicality and the concretisation of mathematical concepts. Her Montessori pre-service teacher training, had inculcated in her the core value and need ‘...to teach the mathematical concepts from a very concrete base’.

Pamela one of the foundation phase teachers in the sample also outlined how her primary teacher identity could be attributed mainly to her initial teacher and phase specialisation training at teachers college, as she said,

‘in my training I was supposed to teach many subjects, before OBE came in I was told you have to teach languages you have to teach mathematics, you have to teach religious education’.

Pamela’s initial teacher training foregrounded her foundation phase specialisation being whilst Belinda’s reinforced a positive maths identity. Belinda and Pamela’s interview utterance shows that their initial teacher training influenced their primary teacher identities.

**Further maths training or education**
There have been few cases in the maths education literature that discusses how further formal maths education training influences one’s mathematical identity. Two of Lerman’s (2012a; 2012b) studies have been particularly useful in this regard. Taking a cue from Lerman’s studies we want to argue that further training in maths education has an impact on one’s mathematical being. In our sample of study two intermediate phase teachers Robert and Calvin had attained Bachelor of Education degrees with an intermediate phase maths component. Both teachers had emphasised during the interview how their training through the Rhodes Maths Education Programme (RUMEP) had fashioned their mathematical understanding and practice.

Robert who regarded himself as being ‘in charge of Mathematics’ at his school had said of his further maths training programme,

‘RUMEP really supported me in understanding the teaching of mathematics….understand maths more deeper and broader….to really understand yourself (reflective practitioner) and understand the learner and how he learns’.

Furthermore RUMEP had introduced Robert to ‘learning theories… mathematical theories’ and ‘connection between a theory what a theory is suggesting and how it is demonstrated when you apply it’. Robert’s colleague and friend, Calvin also emphasised how RUMEP has transformed his teaching identity as he explained that,

‘I was at RUMEP and I did my B A there and in there we did something on constructivism and I think that changed my approach on teaching’.

It is quite clear that both Robert and Calvin’s primary maths teaching practices and identities had been influenced by their participation in further maths education training. It is because of this that we argue that further formal maths training does impact and influence primary maths teachers identities.

**Engagement in professional development programmes**

There has been a quite a sizeable number of studies that have investigated mathematics teacher identity formation during professional development programmes (Davis, et al, 2007; Graven, 2003; Graven, 2005; Drake et al, 2001; Van Zoest & Bohl, 2005). Central to these studies has been the argument that participation in maths professional learning programmes ensures the development of a positive maths teacher identity. In its first year running and from the data emanating from the interviews there is evidence of NICLE’s influence on the participants’ maths teacher identity. (See Pausigere and Graven, 2012 for a full discussion of how the NICLE teacher participants’ mathematical identity was being fashioned through participation in NICLE). In this section of the paper we only present Pamela and Ruth’s utterances concerning how their maths teacher identities were being fashioned in NICLE. Pamela admitted that NICLE had changed her perception of maths, her maths classroom practices, as well as her mathematical being, thus she said of the numeracy professional development initiative,

‘I am glad that I am part of this program. It has changed my thinking, it has also helped me to love mathematics. It has taken some fears that I did have, it has also because I love it now, it is easy to do it in my classroom’.
Similarly and through her participation in NICLE, Ruth’s understanding of maths and her maths teaching practices had improved, she had this to say of the primary maths teacher professional learning community,

‘s I think the NICLE programme has given me ideas, it has you know, my own personal understanding of maths, may be it has awakened that interest again and it has supported my, developing my own understanding, thinking about the process and steps of teaching, it has made me understand, given me more ideas of applying the concept that has to be taught and found other ways of engaging the learners’.

Evident from the data presented in this section and core to our argument is that engagement in maths professional development initiatives shapes and transforms primary maths teacher identities. One of the main propositions in the situative-participationist theory is the argument that participation in communities of practice in which any knowledge exists shapes one’s identity and transforms one’s knowledge (Wenger, 1998; Lave & Wenger, 1991). In developing the PMTI model we have found the need to list participation or engagement in professional development programmes as being one of the central components of primary maths teacher identity.

Educational/curriculum reforms or policies
There have been studies on maths teacher identities within education reform contexts (Morgan et al, 2002; Lasky, 2005; Walls, 2008; Parker, 2006; Graven, 2003). The central message in the literature in this category is that education policy and reforms shape and transform maths teacher identity with teachers positioning themselves differently in relation to education policies and reforms. Bernstein has argued that any education reforms shapes and distributed teacher and learner consciousness and identity (Bernstein, 1975). Currently the South African primary education context is characterised by national standardised annual tests and during our interviews we investigated how the sampled primary teachers practices and identities relate to the maths tests. We report in this part of the paper how the sampled teachers’ practices were being influenced by the ANA tests.

Everton admitted being influenced by ANA in her maths teaching practice as she would ‘make sure’ that she ‘exposes’ her learners to the ANA ‘problems put in a different way’. Swallow accepted that her teaching was being influenced by ANA and had this to say,

‘Yes I think so. If you see that all your children across the board are battling with a particular concept then I know that that is the concept that I need to spend more time on, or that I need to revise or that I need to reinforce it’.

Edna also admitted being influenced by ANA in her maths teaching as it gave her the space ‘to do reflections’ on how she could be ‘better’ and how she can ‘go about to increase or improve the current results’ and also to check if she is ‘on the right track’. The discussed interview extracts shows how the aforementioned teachers were positioning themselves and developing maths teacher identities that positively related to the national tests. Curriculum reform or education policies such as national learner tests influence and affect maths teachers’ practicing identities and thus we feel compelled to list this factor as one of the core elements of the proposed PMTI model.
School context
Locally Carrim’s (2003) study has illuminated how resource disparities in different school systems give rise to different teacher identities. Our study however shows that teachers working in well-resourced school have their mathematical identity shaped by the school’s vision and the expected high maths standards whilst teachers in poor resourced schools sculpture their identity in their classrooms during the maths teaching and learning process. The maths departments in these schooling systems are quite different and serve different agendas. We will firstly illustrate these points with the case of two teachers that served in a well-resourced school. Melania and Ruth did teach Grade 3s, at an affluent ex model C preparatory school in a historically white area and according to the latter their school had,

‘a tradition of teaching things in a particular way and they have very good results and not only in numeracy as well as in language … in numeracy …we have been given very specific instruction not just on how to teach but what to teach and what the…emphasise should be on’.

Concurring with Ruth is Melania, who had this to say about their school norms,

‘we have got our own standards that we aspire to, and I must say the Oaks standards have always been very high and very good and the children that have moved off from here and gone to other schools have all been top in Maths in the school that they have gone to’.

In terms of the school departmental arrangement Ruth had Melania as her ‘direct partner’ and the two prepared everything ‘together’. Their school maths department’s structure is according to Ruth ‘very flat, we don’t have a pyramid of any kind’. Teachers in affluent schools foreground their school mathematical vision thus fitting their mathematical identities within their school maths standards. Their school staff departments work collaboratively to overcome classroom maths challenges.

For Calvin who taught in a township primary school their school maths department served as a forum for ‘admin stuff and things like that … how is the learner performing and what measures are you doing to help the learners it is not to fix content based problems’. This indicates that the school maths departments (learning area committees) had an administrative function and where not a forum for deliberating on maths teaching and learning issues. Both Calvin and Edna faced language problems in their maths classes. Calvin who taught in a school with predominately Xhosa learners speakers would usually find a learner in the class who could translate what he said in English into Xhosa. Edna who taught in a school that was in a coloured area also employed a similar strategy during the interview she recalled one learner, Makane Mini who could speak Afrikaans, English and Xhosa and served as the teacher’s translator as Edna would ‘ask her something in English, and then she will ask that person in Xhosa and then she will answer me back in Afrikaans’. Working class schools’ primary maths teachers solved some of their maths classroom challenges collaboratively with their learners, however their schools do not take a strategic view of maths across the entire school, with maths departments rather having more of an administrative function. Clandinin and Connelly’s (2006) study has shown that the school context influences teachers’ professional being. Marsh (2002) and Ensor’s (2001) studies discuss how school contexts shapes and fashions beginning teachers maths teacher identities. The primary teachers in this study had their mathematical identities informed and shaped differently by their schools’ visions/standards, classroom practices and the school’s administrative structures.
School maths learning experiences

Literature on primary maths teacher education has studies that explain how negative school learning experiences affect maths teacher identities (Hodgen & Askew 2007: Askew et al, 2007). Lerman’s (2012b) study also indicate how negative experiences of learning mathematics at school influences teacher identity. Deducing from the literature one could argue that primary maths teacher identity is affected by prior school maths learning experiences. Two of our research participants, Edna and Mary, during the interview illustrated their positive and negative school maths learning experiences which we believe later affected their maths teacher identity. Mary’s mathematical identity was generally weak as she rated herself a 5/10 in terms of understanding of maths yet Edna rated herself ‘between 8 and 9’. Mary admitted to never having ‘had a very good foundation for mathematics especially at high school’, she disclosed her negative school maths learning experience as,

‘….I kind of lost the whole thing of numeracy because when I went to High school there was politics at the High school and we had something like 4 Mathematical teachers in one year and that is when I lost the whole essence of maths and I thought I will never be able to do this’

In comparison to Mary, Edna ‘love(d) numbers’ had ‘a passion for it (maths)’ this must have been because of her positive school maths learning experiences. Such a strong maths identity and a passion for maths according to Edna was both at primary and at secondary school as illustrated in the interview extract;

Interviewer: So you are saying your passion came from school? Primary, High school?
Edna: Primary
Interviewer: Then how did you, went about in secondary?
Edna: It also went very good………..

Edna’s ‘love for numbers’ had motivated her to join the Association for Maths Teacher Education 6 months after joining NICLE. The literature shows that school maths learning experiences do impact later on one’s maths teacher identity (Hodgen & Askew 2007: Askew et al, 2007: Lerman, 2012b) and the same is also indicated empirically by the learning stories of both Mary and Edna, which indicate that their school maths learning experiences did affect and influence their PMTI.

Life maths experiences

For this category we consider life maths experiences that did not take place within the maths classroom and informed by the empirical data we argue that this category like the others enlisted equally influences primary maths teacher identity. Life maths experiences have been shown to influence teachers mathematical being (Marsh, 2002; Askew et al, 2007). Whilst Askew et al (2007) list family influences, Marsh (2002) examines how personal aspects fashion teacher identity. Brief yet illuminating instances from our interviews with Brenda, Mary, Edna and Calvin indicate that encounters within families or one’s neighbourhood do shape or sustain one’s maths identity.

Both Belinda and Mary mentioned their close family relatives as having influenced their approach to learning and understanding maths. Belinda mentions her uncle as having influenced her to be a long-life learner, as she said,
‘I have an uncle, he is a professor, a Doctor actually and um one of the things he instilled, he is my dad’s youngest brother he is a perpetual learner, and he says you can never stop learning’.

Mary though having negative school maths learning experience found the space to reinvigorate her maths identity through her mother,

‘I think my mother triggered some sort of, it intrigued me that she has a mathematical mind and you know I always thought I would be able to work out something like that…my mum has always been a good problem solver……I was intrigued as to how she was able to work out and see patterns in numbers’

For Edna her prior workplace environments before she become a teacher had helped her maintain a strong maths identity in her life as she recalled how she ‘ended up working at a casino, being a surveillance auditor and there was a lot of numbers involved’. Calvin also related to us how his community and teacher colleagues always promoted a maths discourses, thus he would ‘talk a lot of mathematics’ with ‘Pamela …I talk to Nadia...my neighbour….Milicent Bont….van der Wyver….. Louis van Jarveld….my friends, its, I am working with anyone who is doing maths’. The interview information disclosed by Belinda, Mary, Edna and Calvin helps supports part of our hypothesis that life maths experiences do influence primary maths teacher identity and thus justifies our inclusion of this aspect as being one of the key elements in our model.

Other
Though we have tried to mention all the elements that can be factored in coming up with the notion of PMTI we believe that any reader to this paper or researchers can add any component or components that one could consider key to this construct. Thus we leave in our model an unmarked circle space, labelled in the diagram other to allow readers, maths education researchers and primary maths teachers to add any component beside those mentioned in this model. For example reading Van Zoest and Bohl (2008) and Clandinin and Connelly’s (1996) papers one can see the emphasis placed by these writers on how beginning maths teachers’ mentor relations impact on their mathematical being. We would also have preferred to list this as one factor affecting primary maths teacher identity however in our interviews with the sampled teachers this theme never emerged. Leaving a blank space also shows that this model is tentative and still to be reworked and shows our commitment to receiving feedback from other members in the maths education community.

Abridged version of primary maths teacher identity model
The model that we have presented above can be abridged with some components of the model falling under one core element, thus in-service, pre-service and further maths education training can be collectively called (maths) teacher training/education. Subject and phase specialisation could appear under the same heading of subject or phase specialisation. School maths and life maths experiences could appear under the category of school and life maths experiences. School context and education policy and curriculum reforms can be collapsed into the school, district, national context and policies category. The shortened version of the model doesn’t have the other category, for some components that any maths researcher might suggest can fit into any one of these four broad categories, thus for example when one considers the identity of beginning maths teachers entering the profession this
aspect of teacher identity can fall into the school, district, national context and policies category.

**Figure 1.** The Primary Maths Teacher Identity Model.

**Figure 2.** Abridged version of the Primary Maths Teacher Identity model.

**Conclusion**

This paper discusses the core components and develops a tentative PMTI model. In formulating what PMTI entails, we have taken note of the teachers’ voice, the literature on maths teacher identity and the theoretical frameworks which inform our work. The teacher’s
voices are those main themes emerging during the data analysis. Studies focusing on the
notion of teacher identity must pay attention to teacher’s voice. We have drawn here on the
voice of the ten teachers and many larger scale studies to develop this tentative model. The
triangle of teacher’s voice, teacher identity literature and the theoretical framework aid in
formulating and understanding the concept of PMTI. The model developed here is tentative
and part of work-in-progress. We intended to refine the model as we gather more data from
the empirical field- the primary maths teacher professional development community and as
we carry out more interviews with teachers in the second and final half of our longitudinal
research at the end of 2012.

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Operationalizing Wenger’s three modes of belonging in the context of a mathematics teacher enrichment programme

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Abstract
The focus of this paper is the application of Wenger’s, (1998) notion of learning architecture as an analytical framework for evaluating mathematics teacher participation in an in-service professional development programme. Wenger warns of a breach between theory and practice; suggesting the need to re-contextualise the social learning theory into our teacher development programme. To situate our teacher enrichment programme as a community of practice, the paper begins by elaborating on the two design elements of such a community and shows how these relate to our programme. The paper then gives the theory behind the three modes of belonging (engagement, imagination and alignment) and discusses how they will be operationalized in our study. We end the discussion by noting the complexities inherent in such work.

Introduction
The First Rand Foundation (FRF) Mathematics Education Chair located at Rhodes University is one of several initiatives aimed at improving the quality of teaching and learning especially in less privileged communities in South Africa. The Mathematics Teacher Enrichment Programme (MTEP) is at the heart of the Rhodes University chair and involves fortnightly contact sessions with 25 high school mathematics teachers from 13 selected secondary schools around Grahamstown. The conceptualisation of these contact sessions is based on a concept-driven model of teacher development as opposed to a traditional curriculum-driven approach. The underlying theme in all of the MTEP sessions is to grow teachers’ mathematical content knowledge in relation to learning and teaching it in a conceptually meaningful and proficient way. In the broader study from which this paper draws, we were interested to explore the process of change of the participating mathematics teachers’ professional identities through their participation in the MTEP activities and we saw Wenger’s theory as having potential as a framework for theorising such participation. The theory provides a language that foregrounds identity formation and transformation as crucial aspects of teacher learning. Hence the three modes of belonging; ‘engagement’, ‘imagination’ and ‘alignment’; were used as broad categories to examine how teachers participated in and experienced our MTEP activities.

Consistent with those three modes of belonging, the research questions for the broader study in which this paper is located were phrased as follows:
1. To what extent does teacher participation in MTEP allow for the establishment and sustainment of their productive engagement?
2. How do teachers imagine themselves with respect to conceptual teaching through their participation in MTEP?
3. To what extent do teachers’ styles and discourses align with the broader vision of the MTEP activities?
The problem statement
As this paper draws from this broader study which is still ongoing, we do not yet provide complete answers to the above three research questions. Instead we problematised the operationalization of Wenger’s theory which framed the research questions. So in framing the objective of this paper, we begin by tracing the origins of the social learning theory from which we drew the three modes of belonging that anchor our study.

Working within an anthropological framework, Lave and Wenger’s (1991) social theory of learning was developed in a sociological problematic where learning was conceptualised as some form of social participation where people come together to actively engage in the ‘practices of social communities’ and to construct ‘identities’ in relation to these communities. Wenger’s theory could be viewed as a generic one in that communities are ubiquitous hence the concept of community of practice has found a number of practical applications in business, organizational design, government, education, professional associations, development projects, and civic life. Although diSessa and Cobb (2004), wrote with specific reference to constructivism as a “grand theory” their concern as they put it, was that such theories are often “too high-level to inform the vast majority of consequential decisions” (p. 80). Confrey and Kazak (2006) also pointed to the same concern that generic theory does not spell out how the theory translates into practice, how one will yield testable and refutable hypotheses and conjectures, and by what means one can evaluate the quality of empirical data. Specific to educational settings, Confrey and Kazak posit that generic theory lacks artifacts of practice at least at a level of specificity to guide instructional practice suggesting the need for more specific and elaborated bridging between a theory and the specific context in which it is being applied.

Wenger (1998) himself also alluded to this gap between what designers theorise and put on paper and how the design gets realised in practice with specific reference to his theory. He emphasised that; “there is an inherent uncertainty between design and its realisation in practice, since practice is not the result of design but rather a response to it” (p. 233). Within the South African mathematics education context, Adler (1998) argued that social practice theory required re-contextualisation if it was to fully illuminate the complexity of schooling. Specific to teacher development contexts, we also took heed of Graven and Lerman (2003) who suggested that it was a worthwhile challenge to relate Wenger’s powerful ideas about learning to the process of becoming a teacher of mathematics. So in view of the fact that the three modes of belonging that framed this study were drawn from such a generic theory, we took cognizance of this need to close such gaps in theory and practice by elaborating on how we hoped the theory would be realised in practice in the context of our activities in MTEP. We quickly note and acknowledge Adler’s (1998) observation that Wenger’s theory does not transfer unproblematically into knowing and learning about the practice of school mathematics yet it is a fate of academics to have our work theorised and more often re-contextualised out of our fields and into the field of mathematics education.

Objectives of this paper
To initiate this theory-to-practice process, certain streams of thought were considered as a way to generate a conceptual schema for framing the activities of the MTEP programme. Among the notions that we considered we found the concept of a ‘mental model’ (VanderVen, 2000) more appropriate to push our argument forward. A mental model is described as the internal coherent frame of reference used (a) to represent our worldview, (b) to integrate our experiences and (c) to draw upon for problem solving and decision making (VanderVen, 2000). In this sense, the mental model then becomes the internal determining
factor of what actually gets implemented in practice and determines the practitioner’s response. The aim of this paper therefore is to provide the reader with our ‘mental model’ of how we intend to operationalize Wenger’s three modes of belonging in the specific context of our MTEP programme. In short we are interested in answering the following questions:

1. In what ways do we see our mathematics teacher enrichment programme as a community of practice?
2. What are the specific indicators of engagement, imagination and alignment that are going to guide our investigations of teacher participation?

In each of the following sections, we now provide detailed theoretical descriptions of the key features of Wenger’s model intertwined with specific features of the MTEP that help us link the theory (Wenger’s) and the practice (MTEP).

MTEP as a Community of practice
In order to situate MTEP as a community of practice, we discuss two important elements of design/identification of a community of practice and participation by members within that community of practice.

Design of the MTEP Programme
Communities of practice are ubiquitous but a common thread that runs through them is that they are ‘groups of people who share a common concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis’ (Wenger, McDermott & Snyder, 2002, p. 4). Communities of practice have also been described in terms of people who engage in a process of collective learning in a shared domain of human endeavour: a tribe learning to survive, a band of artists seeking new forms of expression, a group of engineers working on similar problems, a clique of pupils defining their identity in the school, a network of surgeons exploring novel techniques, a gathering of first-time managers helping each other cope (Wenger, 2006). Not everything called a community is a community of practice. A neighbourhood for instance, is often called a community, but is usually not a community of practice. According to Wenger (2006), three characteristics are crucial for the constitution of a community of practice:

**The domain:** A community of practice is not merely a club of friends or a network of connections between people. It has an identity defined by a shared domain of interest. Membership therefore implies a commitment to the domain, and therefore a shared competence that distinguishes members from other people. The domain is not necessarily something recognized as "expertise" outside the community. A youth gang may have developed all sorts of ways of dealing with their domain: surviving on the street and maintaining some kind of identity they can live with. They value their collective competence and learn from each other, even though few people outside the group may value or even recognize their expertise.

**The community:** In pursuing their interest in their domain, members build relationships that enable them to learn from each other. They engage in joint activities and discussions, help each other, and share information. Having the same job or the same title does not make for a community of practice unless members interact and learn together. The banking officers in a large company or learners in some South African high schools may have much in common, yet unless they interact and learn together, they do not form a community of practice. But
members of a community of practice do not necessarily have to work together on a daily basis.

The practice: A community of practice is not merely a community of interest-people who like certain kinds of sports and support certain sporting clubs, for instance. Members of a community of practice are practitioners who develop a shared repertoire of resources: experiences, stories, tools, ways of addressing recurring problems—in short a shared practice. This takes time and sustained interaction hence the development of a shared practice may be more or less self-conscious. The tyre engineers at an auto manufacturer may make a conscious and concerted effort to collect and document the tricks and lessons they have learned into a knowledge base. On the other hand, health care practitioners who meet regularly for lunch in a hospital cafeteria may not realize that their lunch discussions are one of their main sources of knowledge about how to care for patients. Still, in the course of all these conversations, they have developed a set of stories and cases that have become a shared repertoire for their practice.

In summary, we could say a community of practice has an identity defined by a shared domain of interest, in which members build relationships to enable them to learn from each other and the members must be practitioners. It is the combination of these three elements that constitutes a community of practice and it is by developing these three elements simultaneously that one cultivates such a community of practice.

In locating these elements within the MTEP programme, we would like to start with the domain of interest of our activities and point out that the participating members are Mathematics Teachers at Further Education and Training (FET) level. The programme is very clear about who should be a participating member in that it includes only teachers of Mathematics in the FET band. So the domain is defined as FET mathematics teaching.

In terms of building the community, in MTEP we engage in joint activities and discussions, help each other as mathematics teachers and share information. Our energies are directed towards a common goal of teaching mathematics in a conceptually meaningful and proficient way. So in that sense we see ourselves as a group of mathematics teachers, who are making a conscious and concerted effort to collect and document into a knowledge base, the tricks and lessons we have learned about teaching mathematics for conceptual understanding. In pursuance of that objective we hold both our facilitators and participating mathematics teachers accountable to working towards achieving this goal. It is like a thread that runs through all our activities.

In terms of practice, MTEP participants are practising teachers hence practitioners who are interested in developing a shared repertoire of resources. In order to enable our members to access this repertoire of resources we have outsourced and resourced the participating schools with a variety of teaching/learning materials. We have also provided the participants with reading and teaching materials both as hard copies and internet references that set out the project’s agenda. To compliment the reading and teaching materials, we also invite facilitators both internally (within the institution) and externally who are specifically briefed on the programme’s vision vis-à-vis teaching for conceptual understanding as opposed to teaching directly to the curriculum. The facilitators then provide practical models, during the fortnightly sessions, exemplifying what it might mean to teach mathematics conceptually. Examples that quickly come to mind include how some facilitators teased out mathematical concepts embedded in a traditional Xhosa dance, how cubic wooden blocks could be used to teach number pattern, area and volume of shapes and how a ‘Calcudoku’ (a new additive
number puzzle similar to Sudoku) could be useful for teaching reasoning with number and working with the four number operations. While no curriculum specifies the use of such strategies, it is the richness of the mathematical concepts that emerge from such interactions that appeal to the participating teachers and which we hope will translate into their practices. These design characteristics enabled us to argue for the MTEP programme as a community of practice.

**Participation by members on the MTEP Programme**

The concern we have for the broader study from which this paper draws is about learning in that we would like mathematics teachers to come together in a community of practice and continue to learn how to improve learners’ learning. Although this process of belonging to or becoming a member of a certain community is conceptualised in general as ‘learning’ by Sfard (1998), as learning is incidental, the MTEP programme has special elements that resonate with Wenger’s (1998) notion of a ‘learning community of practice’. For Wenger such a community “includes learning not only as a matter of course in the history of its practice, but at the very core of its enterprise” (p. 215). Our view is that MTEP fits this special definition of a ‘learning community of practice’ as it puts the development (learning) of an effective mathematics teacher at the core of the activities. Consistent with this vision, we want to explore the extent to which the MTEP programme offers an environment within which this learning community of mathematics teachers is formed and subsequently flourished and to what extent the programme offers the participants opportunities to explore new ways of teaching mathematics and to develop their identity as professionals.

According to Brosnan and Burgess (2003), although considerable care and thought may be given to a design for learning, how that design is realised in practice will always differ. The degree to which a design is realised in practice is determined by members’ participation or non-participation. Wenger argues that our relation to communities of practice involves both participation and non-participation. In Wenger’s conception of a learning community of practice, learning is evidenced when there is increased participation in mutual and meaningful activities; negotiating and making meaning; and developing a sense of becoming and belonging within the community of practice. To be competent is to be able to engage with the community and be trusted as a partner in these interactions. In this process of learning or participating, identities are formed and transformed in relation to these new communities of practice through a process of reconciliation because ‘we are coming into contact with communities to which we do not belong’, hence in Wenger’s graphic words, we will be ‘… catching, as we peek into foreign chambers, glimpses of other realities and meanings’ (1998:165). However, Lave and Wenger (1991) alluded to a paradox that emerges as a result of this ‘peeking into foreign chambers’ in that the resultant identity wherefrom can either be a vehicle for participating in the community of practice, or it can also lead to non-participation. This is due to the fact that particular social arrangements in any community of practice may constrain or facilitate movement towards fuller participation. It was from this observation that Wenger (1998) suggested that in order to understand learning in relation to identity formation and communities of practice, three modes of belonging referred to as ‘engagement’, ‘imagination’ and ‘alignment’ should be considered. Wenger (2000) emphasises the need for these three modes of belonging to work together in promoting identity formation and full participation and Goodnough (2010) reiterated that in productive communities of practice, all three modes of belonging are highly connected and operate in concert. It is for that reason that in this paper we are interested in operationalizing them in the context of the MTEP programme.

**Engagement**
According to Clarke (2008, p. 36), engagement provides a means for community members to define, maintain, and negotiate their activities and practices, and creates space for creating and recreating identities. This involves communities of individuals engaged in actions that are mutually negotiated. It moves beyond the notion of groups, teams, or networks and involves relations that are complex, thus allowing for the establishment and sustainment of ongoing activities. Through ongoing negotiation, a joint enterprise develops over time, resulting in a shared repertoire that guides the community and provides the impetus for continued learning. Through participation in a community or several communities, shared trajectories or pathways for learning are formed. Identity formation is as much about non-participation (the communities we choose not to join) as it is about participation. Engagement as a mode of belonging allows us to construct ourselves in a constant process of negotiation and involves the interplay between participation (engaging in activities and enterprises with others as members of social communities). In learning to teach, teachers engage in shared activities and practices of the teaching community (e.g. designing curriculum materials, creating learning environments that are student-centred, using assessment and formative and summative evaluation). Engagement is all about mutual participation (and choosing not to participate) in meaningful activities and interactions. It emphasises the formation of communities of practice and rests upon shared, meaningful activities that produce shared artefacts and contribute to community-building conversations as part of the negotiation of new situations. “As a context for learning, engagement is not just a matter of activity, but of community building, inventiveness, social energy, and emergent knowledgability” (Wenger, 1998, p. 237). It suggests doing things together, talking, producing artifacts. The ways in which we engage with each other and with the world profoundly shape our experience of whom we are (Wenger, 2000). We learn what we can do and how the world responds to our actions. Social relationships are fundamental to an effective learning community and engagement requires relationships founded on trust that allow participants to take risks and explore new ways of negotiating meaning in a supportive environment (Brosnan & Burgess, 2003). For a learning community to be effective it must support engagement in part by allowing participants the opportunity to share their histories – what they have done and what they have been.

The key characteristics that emerge from this description of productive engagement include mutual negotiation of activities and participation, provision of a supportive environment, allowing participants to take risks, establishment of relationships founded on trust, establishment of sustained and ongoing activities, shared repertoire that guides the community and allowing participants to share their histories. In the context of researching member participation in MTEP activities, we are therefore interested to understand the extent to which teachers feel that these activities are meaningful to them, are mutually negotiated and are supportive to both their learning as well as their sustained participation. In advocating for teaching for conceptual understanding that is significantly different from teaching to the curriculum, new trajectories or pathways for learning are formed and there is need for inventiveness which in turn places challenges on the teacher. So in terms of productive engagement, we ask; ‘To what extent do teachers feel the MTEP activities are supportive of this inventiveness? What risks are involved and what threats might this inventiveness pose to their own ways of knowing? How do the teachers negotiate their various experiences with such a change?’ So these are some of the questions that would help the broader research tease out teacher engagement on the MTEP programme.

**Imagination**
Imagination refers to an open-minded disposition that requires a willingness to explore, take risks, and make connections in order to create new images of the world and ourselves. It suggests constructing an image of our selves, of our communities, and of the world, in order to orient ourselves, to reflect on our situation, and explore possibilities. According to Wenger (1998, p. 185) “Imagination requires ability to disengage – to move back and look at our engagement through the eyes of an outsider. It requires the ability to explore, take risks and create unlikely connections”. According to Brosnan and Burgess (2003) processes involving the sharing of stories, explanations and descriptions and the generations of scenarios (exploring other ways of doing what we are doing, other possible worlds, and other identities) are examples. Thinking of ourselves as a member of a community of practice requires an act of imagination and these images of the world are essential to our senses of self and to our interpretation in the social world (Wenger, 2000). Imagination involves removing ourselves from direct engagement with practice and examining action as part of the historical pattern established by a community (e.g. teachers), as well as the possibilities for future changes and development. It focuses on self-awareness and reflection in relation to understanding others and their actions, connecting to new trajectories and locating ourselves in broader systems, creating new artifacts and processes, exploring new ways of doing things, and seeing new identities for ourselves.

In terms of researching this mode of belonging, we are interested to understand the extent to which MTEP teachers are open minded about teaching mathematics for conceptual understanding. We would like the MTEP teachers to examine and tell us stories about how our suggested changes and developments may impact their school and classroom functioning, and how they see themselves responding in appropriate ways. By asking the participating teachers to critically examine their practices and the teachers they would like to become we hope this imagination then helps teachers view both themselves and their profession in new ways. But imagination also requires flexibility and creativity to reinvent practices of communities and to create opportunities for novel learning. So we will also be interested to know in what ways teachers see themselves as being flexible and creative in response to the demands of the new ways of teaching that are envisioned by the project.

**Alignment**

As a mode of belonging, alignment involves adhering to the global practices of the community (Goodnough, 2010). Aligning with the practices and discourses of a broader community allows members to direct their energies towards common goals and promotes the coordination of efforts. It involves establishing common ground and defining broad visions. For example, within communities of practice operating in schools and/or districts, teachers may work towards creating safe and caring school environments by addressing issues related to school violence, student absenteeism, sexual orientation and so forth. On the other hand, alignment may also have negative implications as it can involve and can result in individuals being disempowered if they adhere to practices without meaningful engagement in those practices. Teachers may feel powerless if asked to implement the ideas of others or if they have not had input into the decisions that affect their schools and classrooms. This may result in a lack of collaboration and little likelihood that new practices and ideas will be enacted.

The focus, in alignment, is on linking activities within a particular learning community to external and broader issues which lie beyond the boundaries of that community (Brosnan & Burges, 2003). It is this mode of belonging that may be most significant when trying to make a distinction between professional and non-professional practice. Wenger (1998) draws attention to alignment as a mechanism for learners to connect activities undertaken within a particular learning community with broader styles and discourses. The broader styles and
discourses include the code of practice of the professional body that governs standards of practice for a participant. Saunders (1998) emphasised that professional practice can be conceptualised as the application of values … to frame and guide routine practices in the workplace (p. 171). Alignment describes a process of coordinating perspectives and actions and finding a common ground from which to act. It entails making sure that our local activities are sufficiently aligned with other processes so that they can be effective beyond our own engagement. The concept of alignment as used here does not connote a one-way process of submitting to external authority, but a mutual process of coordinating perspectives, interpretations, and actions so they realize higher goals.

In terms of researching this mode of belonging on the MTEP programme, we are interested to hear stories from teachers that reflect alignment/non alignment with the broader and not only immediate concerns of the project. Our immediate concern in teaching for conceptual understanding yet the FRF Mathematics chairs are projects which were born out of a more national and even global concern that learners were underperforming in mathematics. So for example how do the teachers see their participation on the MTEP programme impacting on the pass rates in the province and in the country at large? Another more global concern is that teachers lack skills for effective teaching of mathematics. How do the MTEP teachers see their participation on this programme contributing to this more global agenda, and do they see such ideas as teaching for conceptual understanding impacting on the general concern that teachers lack mathematics teaching skills? So putting all these ideas we see the study following the path depicted diagrammatically in figure 1.

Figure 12 A diagrammatic modelling of the study

The whole study aims to make sense of the teachers’ participation, hence identity formation, within MTEP as a community of practice. We conceptualised this identify formation in accordance with Sfard and Prusak’s (2005) notion, ‘as a narrative told about oneself’ i.e. identities may be defined as collections of stories about persons. These can be split into two subsets: current/actual identity, consisting of stories about the actual state of affairs, and designated identity, composed of narratives presenting a state of affairs which, for one reason or another, is expected to be the case. The authors’ main claim is that learning may be thought of as closing the gap between current actual/identity and designated identity, arguing that whatever the case, learning is often the only hope for those who wish to close a critical gap between their actual and designated identities.

So in our data collection process we intend to interview teachers at the beginning (in order to make sense of both their current and designated identities) and at the end of the data collection period (in order to compare their current and their previous designated identities). This will enable us to make judgement as to whether or not learning or full participation in the MTEP programme took place. Within these interviews we interrogate Wenger’s (1998)
three modes of belonging (engagement, imagination and alignment) in order to make sense of the teachers’ identity formation within MTEP as a community of practice. These interviews will be followed by video recordings of eight lessons (four lessons of two teachers who joined at the beginning of the project and four lessons of the teachers who joined a year later) in total within the sixteen months period. The video recording will form the basis for post observation interviews. The purpose of the post observation interview is to elicit stories of how their conceptual teaching is shaped through their participation in MTEP.

Discussion and implications
In this paper, two questions guided our argument. Firstly we were interested in demonstrating why the MTEP programme is indeed a learning community of practice. We have shown how in a community of practice members are bound together by their collectively developed understanding of what their community is about and that they hold each other accountable to this sense of joint enterprise. In this sense we argue that in the MTEP programme we see a group of mathematics teachers, who share a common concern about poor performance in mathematics and who would like to improve that through deepening their knowledge and expertise about teaching in conceptually meaningful ways. MTEP teachers do so by interacting fortnightly on an ongoing basis. A second feature of communities of practice is that members build their community through mutual engagement. They interact with one another, establishing norms and relationships of mutuality that reflect these interactions. In the MTEP programme we have already started noticing the participating teachers organising themselves for workshops on specific topics of interest e.g. linear programming, problem solving related to graphing of quadratic functions and financial mathematics. Thirdly, communities of practice have produced a shared repertoire of communal resources, and to be competent is to have access this repertoire and be able to use it appropriately. In the MTEP programme, we have gathered over time a pool of resources that members share and make use of in their schools. In summary, because the participating teachers on MTEP become connected to the programme through coordination of their energies, actions, and practices; in our view they constitute a ‘community of practice’ in Wenger’s (1998) terms.

The second question guiding our analyses concerned the specific indicators of the three modes of belonging. Brosnan and Burgess (2003) suggested that in order to understand learning in relation to identity formation and communities of practice, three modes of belonging referred to as ‘engagement’, ‘imagination’ and ‘alignment’ should be considered. From the key indicators that emerged from the description of productive engagement, we intend to tease out stories from teachers about the extent to which the environment in MTEP affords them mutual negotiation of activities and participation, provision of a supportive environment, allowing participants to take risks, establishment of relationships founded on trust, establishment of sustained and ongoing activities, shared repertoire that guides the community and allowing participants to share their histories. In terms of researching imagination we are interested to understand the extent to which MTEP teachers are open minded about teaching mathematics for conceptual understanding. In terms of teasing out alignment stories, we are interested to know how the MTEP teachers see their participation on this programme contributing to this more global agenda, and whether or not they see such ideas as teaching for conceptual understanding impacting on the general concern that teachers lack mathematics teaching skills. These would guide the stories we intend to tease out from the teachers.

Conclusion
In this paper we have shown how we intend to re-contextualise Wenger’s theory in the context of the MTEP activities. While Wenger offers a general theory of social practice drawing from apprenticeship learning, we take heed of the observations made by Adler (1998) that a theorising of learning from successful apprenticeship contexts might not be able to unproblematically illuminate or explain teaching/learning relationships which are hugely complex. However, delving into this complexity was beyond the scope of this paper. After all, learning is not a unitary phenomenon, and thus not amenable to one all-embracing theory. Despite the concerns raised by researchers in mathematics education about the transferability of Wenger’s theory, his notion of learning through participation in communities of practice appropriately and powerfully illuminates how knowledge about teaching is acquired in their ongoing participation in teaching communities such as MTEP. The theory suggests that through a process of legitimate peripheral participation newcomers interact with old-timers in a given community setting, becoming increasingly experienced in the practices that characterise that community, and gradually move towards fuller participation in that community. However, social arrangements in any community may constrain or facilitate movement towards fuller participation hence Wenger suggests that this level of participation has to be examined through the three modes of belonging i.e. engagement, imagination and alignment. So while the theory does not transfer unproblematically, into other contexts different from apprenticeship learning, we found it offering powerful insights and allowing us to examine the resources made available in the MTEP programme and their possible effects on members’ peripheral or full participation.

References
An examination of pupil difficulties in solving geometry problems

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This paper builds on previous work and represents the next iteration of developmental work relating to Grade 12 pupils’ activity in Euclidean geometry problems by examining the strategies they employ that may be causal to their failure in some of these problems. Previous work indicated that pupils exhibited significantly lower competence in developing deductive proofs compared to the calculation of quantities, even in different types of problems drawing on similar propositions. The paper draws on empirical data of pupils who were tested on matched computation-type and proof-type problems to explore what they did more carefully. The idea that pupils may be employing a series of visual templates that are related to the geometrical diagrams to facilitate their reasoning, in the way that said templates represent the Euclidean geometry theorems, is considered in this paper. Finally, the paper suggests that pupils appear to lack insight into the relations between propositions with reference to announced geometrical structures.

Introduction
In this paper I discuss aspects of the examination performances of sixteen Grade 12 pupils, from five high schools, who participated in a teaching programme to prepare them for the 2011 Mathematics Paper 3 matriculation examination, as the content examined in Paper 3 was not offered at their schools. The full cohort comprised twenty-five pupils, but only sixteen availed themselves for the two tests discussed here. The examination responses of 3 pupils are considered in some detail. MacKay (2011, 2012), reported that the teaching sessions suggested that, in addition to the very limited exposure to Euclidean geometry, that (a) the pupils’ mathematical activity was, generally, regulated in a manner that did not enable them to make coherent use of propositions appropriate to the problems they attempted to solve, and (b) the teaching of the reading and writing of mathematics proofs was not a common practice in their schools. Nevertheless, sixteen of the twenty-five pupils did pass the final 2011 Grade 12 Mathematics Paper 3 examination.

A pilot study set up to investigate the pupils’ performances on computational-type and proof-type problems (MacKay, 2011) indicated that even where both types of problem draw on the same propositions, pupils exhibited a greater facility with techniques for solving problems requiring the calculation of quantities (angles, lengths) than they did with arguing deductively and writing proofs. The study had hypothesised that in many instances pupils were not drawing on the necessary propositions in an expected manner, and that were often employing some or other resources in their treatment of different forms of the problems. A follow up study argued that many of the pupils where using formulae that do the work of various propositions of Euclidean geometry rather than using the propositions directly (MacKay, 2012). An apparent consequence of this kind of problem-solving strategy is that pupils struggle to solve problems that require them to use geometry propositions directly and to express their work in terms of those propositions, as is the case with proof-type problems.

In this paper I will consider the assertion of Dowling (2012) that pupils may use a strategy consistent with a mix of discursive and non-discursive semiotic modes to solve geometry problems. The discursive mode is “available within language” while the non-discursive mode
is accessed through interpretation of diagrams and the use of mathematical operations (p. 14).

So, Dowling (2012) says that pupils (and sometimes their teachers) could approach geometry by reconfiguring the theorems that are propositional, as visual templates. Essentially pupils could engage in pattern recognition, where there are canonic forms that must be recognised to constitute templates, which are used in solving geometry problems. Pupils could then constitute a number of geometrical topics as a co-ordination of these templates and the pupil then uses the series of acquired templates to solve problems, rather than work from the propositions. Templates are used as resources for constituting procedures in the same way as procedures are constituted in the teaching and learning of school algebra.

**A few remarks on method**

In MacKay (2011), I discussed the use of two tests, Test A and Test B, consisting of three matched pairs of problems that were constructed to enable a more careful exploration of pupils’ unsuccessful attempts at solving geometry problems. Matching the test items meant that pupils were expected to draw on the same set of propositions when solving the problems. Test A was made up of computational-type problems and Test B of proof-type problems. The two tests were administered one week apart and in both instances the same information was provided diagrammatically and discursively. A quantitative analysis of the pupils’ answers, specifically a measure of the correlation between their performances on the test, globally and by matched problem, was produced and provided the basis for discussion of particular problems in this paper.

The pupils’ aggregate performances across the two tests are represented by the graph in Figure 1, from which it can be seen that students, generally, performed better on Test A (computational-type) than they did on Test B (proof-type).

![Figure 1: Pupils’ aggregate performances across Tests A and B.](image)

The value of the correlation coefficient ($r = 0.87417$) and the line-of-best-fit, for the sample, clearly points to a fairly strong linear positive correlation between the performances across the two tests, indicating that the hypothesis in MacKay (2011) that pupils tend to perform better on computational-type problems than they did on proof-type problems is not unreasonable. The problem for this paper is to begin to draw out ideas as to the possible reasons for this trend in the performances of Grade 12 pupils on geometry problems.
In MacKay (2012), I considered the pupils’ responses to Question 3. In this paper I consider the idea that pupils use templates to solve the problems and, once again, for the sake of brevity, I focus on pupils’ responses to the question shown in Figure 2.

**An analysis of selected pupil test responses**
The responses of selected pupils, given the limitations on space, are now examined. I focus my attention on what appears to be going on, rather than on providing proof of what pupils are actually doing.

![Diagram](image)

**Figure 2**: Question 3 from Grade 12 Paper 3 test, showing the variations in the problem statements.

The analysis will focus on pupils’ work in Question 3. In both variations of the test question, the pupils are expected to draw on the same sets of propositions in the respective sub-questions, as indicated in Table 1. This is also the case in Question 1 and 2.

**Table 1**: Propositions on which pupils must draw to answer sub-questions in Question 3 of
### Tests A and B

<table>
<thead>
<tr>
<th>Test A</th>
<th>Test B</th>
<th>Propositions</th>
</tr>
</thead>
</table>
| Q 3.1 & 3.2 | Q 3.1 | (a) The angle between a tangent and a radius, at the point of contact, is a right angle.  
(b) The opposite angles of a quadrilateral are supplementary |
| Q 3.3 (a) | Q 3.2 | (a) The angle between a tangent and a chord is equal to the inscribed angle subtended by that chord in the alternate segment.  
(b) If two parallel lines are cut by a transversal, the pairs of alternate angle will be equal.  
(c) If two lines cut, the vertically opposite angles are equal. |
| Q 3.3(b) | Q 3.3 | (a) The angle at the centre of a circle is double the inscribed angle subtended by the same arc or chord.  
(b) The opposite angles of a cyclic quadrilateral are supplementary. |
| Q 3.4 | Q 3.4 | If a side of a quadrilateral subtends a pair of equal angles, on the same side of it, then the quadrilateral is cyclic. |

However, I first discuss the actual test questions, shown in Figure 2, with reference to Dowling’s notion of visual templates. Whether or not pupils are deploying discursive or non-discursive semiotic resources, drawing on the same sets of propositions or doing something else is not clear across the range of test respondents. Dowling’s (2012) suggestion that pupils use visual templates implies that “[they] can potentially recognise the template in the problem graph” (p. 14), that is, the problem-solving resources are located in the drawing that accompanies the text at the head of the problem. The template resources applicable in our question are shown in Figures 3 – 7. Presmeg (1992), refers to instances when pupils’ reasoning is facilitated by the use of diagrams, as metonymic usage, says:

… a situation in which some category or member or submodel is used (often for some limited or intermediate purpose) to comprehend the categories as a whole. (p. 600).

According to Dowling, pupils may use these or other templates to solve geometry problems. So, for example in Test B Question 3.3 (Figure 8), to prove that $\hat{A} + \hat{B} = 180^\circ - 2\hat{C}$, pupils may say $\hat{A} = \hat{C}$ (using the ‘angle between a tangent and a chord’ template), then $\hat{B} = \hat{A} = \hat{C}$ (using the ‘tangents from the same external point’ template), and then $\hat{A} + \hat{B} = 180^\circ - (\hat{A} + \hat{B}) = 180^\circ - 2\hat{C}$ (using the ‘sum of angles of a triangle’ template). But he acknowledges that the use of theorems may be an alternative to deploying visual templates. In other words, pupils may use the discursive text to deploy the relations between the elements that constitute the geometrical theorems. However, given that the text at the head of the problem does not fully enable the drawing of the diagram, pupils will have to additionally rely on the non-discursive text.
Figure 3: Geometrical template: angle between a tangent and a radius

Figure 4: Geometrical template: angle between a tangent and a chord

Figure 5: Geometrical template: angles subtended by the same chord theorem
Figure 6: Geometrical template: tangents from the same external point

Figure 7: Geometrical template: sum of angles of a triangle

But each of these visual templates, as indicated by Dowling (2012), can be an enunciation of more propositions than what may be required in a given situation. So, the template in Figure 6 could, for example, indicate the following theorems:

(a) the two tangents drawn to a circle from a common external point, are equal in length
(b) the tangents are perpendicular to the radii of the circle, at the points of contact
(c) the circle is the locus of all point equidistant from a point.

Three pupils’ answers to selected questions are now discussed. Question 3.1 (Test B) requires pupils to prove that a quadrilateral is cyclic. Firstly, Lionel offered the solution shown in Figure 9. In proving that $\hat{T} = 180^\circ - 2x$ (Figure 9), it is evident that the pupil is able to string together a coherent sequence of mathematical statements. However, he incorrectly applies the tangent-chord proposition to arrive at the statements $\hat{A}_1 = \hat{B}_2 = x$ and $\hat{B}_1 = \hat{A}_2 + \hat{A}_3 = x$. Experience tells him that ‘the angle between a tangent and a chord’ must equal another angle at the circumference of the circle, but he fails to recognise that the chord must subtend the angle at the circumference or he does not know what the latter means. From this error, $\hat{O}_1 = 180^\circ - 2x$ emerges, and possibly recognising that he must describe the relationship between a pair of opposite angles of the quadrilateral, he accepts equality as the criterion for proving that the quadrilateral is cyclic. It is also possible that not having proved the known
relation and being unable to recover, he makes the final required statement and proceeds to the next question.

In Dowling’s terms, it is possible that Lionel may have deployed geometrical templates (‘tangents from the same external point’ and ‘sum of angles of a triangle’ templates) to calculate the values of \( \hat{T} \) and \( \hat{O}_1 \), but uses an inappropriate template resource when applying the tangent-chord proposition.

The opening statement in Figure 10 demonstrates the pupil’s awareness that the angle at the centre of the circle must be double some other angle, in the way that she states \( \hat{O} = 2x \), but there is no evidence of making connections with other elements of the ‘central angle’ proposition. Her answer suggests that she may be deploying a geometrical template (‘sum of angles of a triangle’) in \( \text{ATB} \) and a similar one in \( \text{AOB} \). Sandra’s final statement indicates that she knows what the relationship between a pair of opposite angles must be (that is, ‘the sum of a pair of opposite angles = 180°’) to prove the announced geometrical object, but this is not clearly demonstrated.
Finally, I discuss Simon’s answers to Question 3.3 in both Test A (Figure 11a) and Test B (Figure 11b), in which candidates were required to calculate the value of a particular angle, either in degrees or in terms of another angle. In Figure 11a, Simon appears to appropriately use the tangent-chord theorem to state that $\hat{A}_1 = \hat{C}$. He may appropriately have related the elements of the proposition, but he may instead have used the ‘angle between a tangent and a chord’ geometrical template to deduce that $\hat{A}_1 = \hat{C}$. Similar arguments can be made for the way in which he correctly shows that $\hat{C}KP = 70^\circ$, but like Lionel, does not use the ‘tangent-chord’ proposition appropriately in the latter part of Figure 11a or in his response to Question 3.3 of Test B (Figure 11b) where an incorrect proof consequently emerges from the inappropriate use of the propositions. In Figure 11b, a correct final statement emerges from a series of incoherent mathematical statements and justifications. However, there is evidence (in Figure 11a) that Simon was able to prove that $\hat{K}_1 = 70^\circ$, by deploying the ‘vertically opposite angles’ proposition. Thus, it appears that Simon is able to solve computational-type Question 3.3 (Test A) with relative ease but has great difficulty with comparable proof-type Question 3.3 (Test B).

One could attempt to address the discrepancy by arguing that the emergent difficulty in the answer to Question 3.3 (Test B) is a consequence of the absence of the actual value of $\hat{A}_1$. This idea was considered in MacKay (2011).

![Figure 11a: Simon’s solution to Question 3.3 on Test A](image)

![Figure 11b: Simon’s solution to Question 3.3 on Test B](image)


Test B

Concluding remarks

In Question 3.1 (Test B), the proposition that fixes quadrilateral AOBT as cyclic derives from relations between propositions that refer to geometrical objects that are internal to the quadrilateral, and objects that are external to it. MacKay (2012) indicates that it was possible that Lionel and Sarah are attempting to prove that the quadrilateral is cyclic by operating only on elements that are internal to the quadrilateral. Similarly, in Question 3.3 (Test B), where \( \hat{C} \) is an inscribed angle of the circle, while \( \hat{A}\hat{B} \) is an element of the cyclic quadrilateral, Simon correctly identifies the angle between the tangent and a chord, but the ‘inscribed’ angle reference remains internal to the quadrilateral, generating the inappropriate relation \( \hat{B}_1 = 2. \hat{C} \). Concatenations of arbitrary statements emerge from Simon’s inability to recognise the appropriate relations between geometrical entities internal and external to the quadrilateral (\( \hat{C} \rightarrow \hat{B}\hat{O}\hat{A} \rightarrow \hat{A}\hat{B} \)) and easily solve the problem. Jones (2002) ascribes this dilemma to an inability to “produce a short sequence of statements to logically justify a conclusion and to understand that deduction is the method of establishing geometric truth” (p. 130).

However, I have conjectured that pupils may have reconfigured the propositions as visual templates, which they recognised as canonic forms to constitute templates, and enabling pupils to deploy the template resources to constitute procedures. Instances of pupil work in which this may have occurred were identified. However, while the use of visual templates may have generated series of statements, it was not clearly evident that a coherent proof emerged. The work of Sandra in Question 3.1 (Test B) is an instance where possible use of visual templates may have generated the statements and reasons.

\[
\hat{A}_3 + \hat{B}_2 = x = \hat{B}_2 \quad \text{(Base 's =), and}
\hat{A}_1 = x \quad \text{(Base 's =)}
\hat{B}_1 = x \quad \text{“}
\]

It is, though, not evident that the appropriate elements constituting the proposition supporting the announcement of the intended object, are related as a consequence of the statements shown. Deploying visual templates may also have generated most statements in Simon’s answer to Question 3.3 (Test A), but the inappropriate statement \( \hat{A}_1 = \hat{K}_1 \) (tan/chord theorem) suggests that he may have been doing something else. But while the deployment of visual templates, as proposed by Dowling, may appear plausible, pupils’ may only use these resources to constitute procedures when the diagrams are given in addition to the text at the head of the problem. As subject assessment guidelines require that diagrams always be given in assessment tasks, the text at the head of the problem generally does not enable pupils to draw their own diagrams. Given the latter context, the deployment of visual templates no longer appears very plausible.

In previous work I also suggested that pupils’ responses, particularly in the way they cannot successfully solve proof-type problems, appear to use formulae to substitute for propositions (see also Hilbert, 1927). \( \hat{A} + \hat{B} + \hat{C} = 180^\circ \) (the sum of the angles of a triangle) or \( \hat{O} = 2. \hat{B} \) (the angle at the centre of the circle is double the inscribed angle subtended by the same arc)
are examples of such formulae. This is indicated by an apparent inability to link propositions relationally. The inclusion of values of angles in the computational-type problems appears to enable the development of strings of statements constituting coherent arguments, possibly because pupils find numbers to be a useful resource. Hilbert & Bernays (1934), in a discussion about the consistency of theoretical systems, say

… one represents the object of a theory through numbers and systems of numbers and basic relations through equations and inequalities in such a way that on the basis of this translation the axioms of the theory become either arithmetic identities or provable assertions (as in the case of geometry) … (p. 4)

The ideas emerging from this developmental work, even though it is based on the actual work of three pupils without any follow-up interviews at this stage, points to pupils not having developed adequate insight into the structures, which Van Hiele (1986) references. Although Van Hiele was reluctant to define structure, he describes it as a “network of relations” (p. 49), for example, “(x + 2)^2” may be seen as a sign to expand the given expression and produce a new equivalent one” (Arnold, 1996: p. 1), whereas insight refers to knowing how to act when we encounter a structure. In other words, knowing what mathematical operations to perform on particular mathematical objects.

Structure is an important phenomenon: It enables man and animal to act in situations that are not exactly the same as those they have met before. Structure saves man and animal from a never-ending life of trial and error … Insight exists when a person acts in a new situation adequately and with intention. (Van Hiele, 1986: p. 24)

Van Hiele (1986) asserts that pupil failure to act on particular structures derives from their lack of insight. In other words, the appreciation and grasp of transitivity, which refers to the ability to recognise relationships among various things in a serial order, has not developed appropriately in relation to geometry, and possibly not in relation to other topics on the school curriculum (see Brainerd, 1973 for a discussion of transitivity as a precondition for seriation).

So, we now see that it may well be the case that the geometrical objects named in problems are focused on in a manner that deemphasises the relations between their immediate constituents and geometrical objects external to them, suggesting that Skemp’s (1986; 1987) distinction between instrumental, relational and formal thinking might be productive for future investigation. In addition, the fact that pupils tend to perform better on computational-type problems suggests that they are able to construct arithmetic relations between quantities that refer to objects that are not necessarily only internal to a specific complex of geometrical objects.

The suggestion that visual templates and/or formulae may be the resources that pupils draw on instead of having insight into the geometrical structures – the relations between propositions – warrants further investigation.

References


SCIENCE & TECHNOLOGY EDUCATION
Making computer applications technology educators’ adaptation to changes relevant in South Africa

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Abstract

The purpose of this study was investigating research questions around Computer Applications Technology (CAT) educators’ adaptation to frequent changes in technology. The paper draws on the latest, most relevant research findings available, in a literature review covering aspects related to novice and experienced educators, methodological weakness and research in the Southern African context. The study is located within a relevant conceptual framework that clarifies issues around technology, Information and Communication Technology, CAT, computer literacy and e-education. The methodology is described, including attention to the importance of dependability and interpretation issues for the qualitative part of the research design, and consideration of issues related to reliability and validity for quantitative designs. The discussion of results provides insight into biographical details of respondents and participants’ responses during semi-structured interviews - these are in some instances connected back to literature. In conclusion, results are organised to answer research questions, implications suggested and recommendations made, along with discussion of the strength and limitations of the study. Finally, the importance of the research reported in this paper is justified in terms of filling gaps identified in literature to make original contributions towards scholarly debate in the field.

Introduction

The performance of computers and the software they use have shown rapid and remarkable development (Goosen et al. 2007). Especially over the last 20 years, significant changes with regard to upgrades and advances in computer and communication hardware and software (including operating systems and application software) have occurred frequently (Goosen, 2004).

These changes have been of such an extent that learning and teaching support materials, such as manuals and textbooks, being used quickly become out-dated and arguably of little value. According to Callaghan et al. (2008), this would mean that the concepts associated with this technology accordingly needs to change, while Andersson (2006) expressed concern about the variable character of education under circumstances where communication of knowledge and competencies change regularly. Tondeur et al. (2007) agree that this also not only brings about changes in terms of the skills for envisaged outcomes, related to knowledge, competencies and views that learners are expected to achieve, but also that education methods and materials must be adapted and changed to keep pace with such changes, to ensure that effective teaching and meaningful learning continues to take place. They go on to point out that information and communication technologies (ICTs) play a significant part in society when computers’ and the Internet’s societal, cultural and financial functions are taken into account. The use of such ICTs is not only observed as having possibilities for revolutionising our lives (Banyard et al. 2006), but, according to the then Department of Education (DoE, 2004), keep on posing novel pedagogical and instructional challenges for organisations worldwide.
Because of the dynamic nature of Computer Applications Technology (CAT), constant changes will have to be made to keep up with new developments. Therefore, when preparing to teach in ICT related fields, educators often need to improvise and draw imaginatively upon knowledge of their subject to exemplify the gist and intention suitably for their learners (Loveless, 2007), by linking learning material to learners’ prior experience and to real life purposes (Callaghan et al., 2008). They face many challenges due to the diversity of and ever-increasing range traversed - teaching should therefore be carefully designed and backed up with educational research.

The authors have first-hand experience with adapting to frequent technological changes, and thus became interested in this topic, after we have had to adapt to the changes that occurred with regard to some of the hardware and software being used over the course of the past several years. Although these changes have a ripple effect on CAT learners, it is especially CAT educators who have to make a plan to implement measures in such a way that effective learning continues to take place, whether or not they have access to updated learning and teaching support materials. We have noticed that some educators struggle to adapt, while others find ways to improve the situation.

**Purpose of study and research questions**

The problems mentioned in the introduction will continue to occur, because technology changes frequently and CAT educators will have to continue to adapt. Although studies like the one by Banyard et al. (2006) state that we often take for granted that such differences will improve our lives, and must therefore be welcomed, there surely must be ways of making adaption easier for educators. The purpose of the study was therefore to investigate the primary research question ‘How do CAT educators adapt to technology changes?’

Secondary research questions to support and extend the enquiry included:

- What role does educators’ experience play when adapting to technological changes?
- What opportunities are available for CAT educators to support change?
- What is the nature of CAT educators’ attitudes towards lifelong learning?

**Importance of research**

According to Kozma (2005), such changes will continually take place as technology progresses in times to come and research should make provision for these changes. Existing research in this and related fields quickly become outdated, but if a start is made towards designing a model to accommodate such technology changes, for instance by using e-books, then learning could be supported in that way. However, Tondeur et al. (2007) warn that the nature of especially educational change is a complex process. This research may therefore be of value for CAT educators to help them cope with frequent changes, and encourage them to adapt and learn from one another about how to manage day-to-day challenges, like the upgrading of software and promote lifelong learning.

This paper therefore not only presents something that has relevance for this SAARMSTE conference, but also by contributing to creating both academic and applicable knowledge for professional growth with ICTs (Mukama & Andersson, 2008). It thus holds research possibilities that could be of value to subject advisors, curriculum- or learning support material developers, and ultimately, to the learner, who receives quality education from a confident and qualified educator.

**Literature review**

Although a study by Ensor (2001) was published more than 10 years ago, it is sufficiently relevant to this research, because it details the potential of relationships between novice educators, and how they can learn from their more experienced colleagues. A more recent
A qualitative study by Anderson (2006) provided a Swedish perspective, and specifically focused on novice educators’ learning related to them using ICTs as instruments to overcome obstacles in their work environments. This study investigated how they create information about education in contexts where ICT is transforming the conditions under which they teach, learn and collaborate with fellow educators.

In the relatively ‘closer to home’ continental context of Africa, Mukama and Andersson (2008) similarly investigated the reflections of novice Rwandan educators on coping with change in ICT-based learning environments. Their findings show that novice educators were enthusiastic to procure ICTs and thrived when administrators provided them with easy access to computers. The novice educators conveyed a clear need to be relied upon and permitted to use their computer related competencies for learning and tuition. However, they also need to have occasion to test different educational approaches that use ICTs (Lim et al., 2007).

The South African White Paper on e-Education (DoE, 2004) states that educators have the responsibility of playing a significant part in creating thoughts, experimenting with examples and applying approaches. According to Lim et al. (2007), discussions between colleagues on their knowledge and practices can be accomplished by engaging in professional circles (Kozma, 2005), together with more extensively using ICTs for communicating (Lai & Pratt, 2007).

In terms of research methodologies, we used a mainly qualitative study like Andersson (2006), and case study type research similar to that of Lim et al. (2007), Hulbert and Snyman (2007), Banyard et al. (2006) and Ensor (2001). The latter author admitted weakness in her study, in that is was limited by only considering a small sample of seven educators. Although the population of CAT educators for this study made the potential number of participants much larger than that (see section on research methodology), the number of principals who agreed for educators to take part in the study resulted in a comparable number of participants. In contrast to the indication by Ensor (2001), that research literature on educator training is generally abundant, this is definitely not the case for CAT. An editorial by Davis (2000), which provides multiple perspectives on change with regard to international contrasts of information technology in educator training, was the only such commentary to be found in a field at least broadly related to CAT. The latter author considered various viewpoints for changing education as a necessity: Educational advances in the technologies being implemented these days are not only inescapable, but will unavoidably present numerous educators with related concerns. They will then welcome such varied viewpoints for interpreting and planning for change.

Although a fair number of the studies cited in this paper were conducted in the South African context, none of these focused in any way on CAT. Even though Hulbert and Snyman (2007) worked in the broader area of ICT, they aimed to determine the reasons why such centres fail. In considering principles for successful ICT teaching, Callaghan et al. (2008) investigated issues broadly related to ICT in education.

**Conceptual framework**

In existing research, a number of concepts/terminology relevant to this research are being confused with each other, are used interchangeably and/or no clear distinction is drawn between certain terms. It is therefore necessary to not only clarify what these definitions refer to in education in general, but also to specify the way in which these will be understood in this research. Whilst it can be considered a reasonable assumption that there is consensus
regarding the meaning of certain terminology, such as what it means when one refers to mathematics, such consensus is not so apparent for the definitions of e.g. technology. According to Banyard et al. (2006), we expect a lot from technology. We like to believe that it brings about improvements related to efficiency and enhances our ways of working. In the education milieu, the transformation of teaching and learning practices through ICTs has been of specific importance. Mentz et al. (2008) therefore point out that a significant amount of research is being done, both in Southern Africa and further afield, in order to understand technology and its position in instruction. In order to standardise for this paper, we will agree with these authors’ view that most classifications and explanations of technology highlights the manufacture of articles and the part of individuals in this development (Mentz et al., 2008). Correspondingly, Reitsma and Mentz (2006) define technology as relating to processes during which knowledge, competencies and resources find application in identified personal requirements and challenges, by solving these through investigation, development, production and assessment. While Goosen (2004) highlights that technology can be regarded as an instrument that encompasses most subjects, Callaghan et al. (2008) calls attention to the fact that the ICT discipline also creates tools for use. As emphasised earlier, fields related to ICTs presently represent some of the most fluid in the educational domain, and classification within these are consequently shifting. Due to our focus on CAT in this research, we will use the following description of information and communication technologies: ICTs combine networks, hardware and software with ways of communicating, collaborating and engaging, enabling data, information and knowledge to be processed, managed and exchanged (Department of Basic Education, 2011).

In the subject CAT, learners study the integration of computer system components (hardware and software) for practical application by efficiently using these to overcome day-to-day challenges. Broadly, CAT can thus be described as the application of computer knowledge, and more narrowly dealing with tools and techniques for carrying out the plans to achieve the desired objectives or solving problems. Similar to what Callaghan et al. (2008) describes for the ICT discipline, CAT has also in recent years expanded to include some elements of commercial web and multimedia development, as well as networking and communication administration.

Another matter that needs to be cleared up pertains to the confusion that exists between CAT as a subject and educational technology as an instrument for instruction and learning (Goosen, 2004). However, where technology is the auxiliary tool in most subjects, it is the primary tool for instruction in CAT. Therefore, within the context of this research, CAT must be considered as subject, as opposed to a tool: the computer is the tool and CAT is a subject that uses it, naturally, among other tools.

One of the primary applications of computers since they appeared on the worldwide instructional scene (Goosen et al., 2007), representing the majority of what takes place in many computer classes, focuses on so-called computer literacy. In the teaching of these, competencies related to keyboarding and data entry, as well as basic computer principles and software applications, such as word processing, spread sheets and/or databases, are traditionally significant elements (DoE, 2004; Goosen, 2004). Because of some obvious overlaps between the subject content covered in CAT, and the application of computer skills as found in computer literacy classes, the general public tends to also confuse these two.

A last avenue investigated with regard to literature that could possibly contribute to this research concerns e-education. The South African White Paper on e-Education describes it as adaptable education that uses ICT resources, instruments and appliances to focus on accessing knowledge, educators interacting with learners within an online setting, collaboratively learning and producing resources and educational encounters (DoE, 2004).
Research design and methodology
It was decided to use a research design approach that involved collecting both quantitative and qualitative data. The use of such multi-method strategies could produce diverse insights regarding topics of interest and augment results’ credibility (McMillan & Schumacher, 2001). These strategies also allow for data triangulation across inquiry techniques and provide the mechanisms for mutual support between qualitative and quantitative research - this could enable a researcher to verify the degree to which assumptions based on qualitative information are reinforced by quantitative perspectives, or vice versa (Maree & van der Westhuizen, 2007).

These also made it possible for us to enhance the depth of results in an approach exemplified by the typology quan + QUAL (Maree & van der Westhuizen, 2007). This meant that data were mainly QUALitative, and placed the emphasis on the qualitative section of the research. However, a small quantitative aspect was also obtained from a summary of educators’ biographical details: As part of their interviews, educators were asked to respond to a one-page survey, in order to collect details that describe the demographics of the respondents in the study in terms of their basic biographical data.

The primary method of data collection employed consisted of once-off, semi-structured interviews conducted by the second author with each educator individually. Like that of Hulbert and Snyman (2007), we developed our interview schedule centred in previous research and a review of relevant literature.

One of the strengths of using the questions in a semi-structured interview as main data collection instrument is the possibility of attaining a measure of objectivity - the methodical use of such a consistent tool aids in offsetting challenges related to researcher subjectivity, while also increasing comparability of responses and facilitating data organisation and analysis.

Another strength of the semi-structured interview is that it enabled the interviewer to modify questions throughout the discussion itself, as questions are used as a guideline, allowing the interviewer an increased amount of choice during the data-gathering procedure (Hulbert & Snyman, 2007).

A limitation of using semi-structured interviews is situated in a possibly biased interpretation of responses, due to relationships that could exist between interviewees and researcher. The second author attempted to counteract problems in this regard by having the data analysed independently by herself and another more experienced researcher (the first author), who had not been involved in conducting the interviews.

According to Reitsma and Mentz (2006) dependability is related to the consistency of research and designates reliability. These authors indicate that involving multiple researchers, as described in the previous paragraph, not only represents one of the strategies for application to achieve this, but, in agreement with McMillan and Schumacher (2001), also provides a method to enhance validity. Then, once agreement had been reached on the descriptive data collected, results could be evaluated and combined for providing a complete representation of the way in which CAT educators adapt to change.

A combination of convenience and purposive sample selection was utilised: Initially, the population for this study consisted of a total of 74 CAT educators, irrespective of gender, race and/or age. They were from convenient geographical locations offering CAT within a district in Tshwane, which was easily accessible and conveniently situated for the researchers, and where eleven principals had agreed to allow educators to take part in this research. Purposive sampling was subsequently used to select a manageable number of participants to interview, that included both male and female educators from all races, and
particularly recently qualified CAT educators, as well as educators with a lot of experience in teaching CAT or other related subjects.

According to Callaghan et al. (2008), lecturers vary both in terms of the level of training they have received, as well as regarding their amount of teaching experience. Participants could therefore be divided into two broad categories:

Newly CAT qualified educators, who graduated after 2006, the year in which CAT was introduced. These educators were typically trained under more advanced technological circumstances.

In comparison, the second group consisted of experienced educators who had to adapt over a period of time – from being educators of various other (sometimes related) subjects, to now being CAT educators.

Like Andersson (2006), we therefore wanted to see if any differences became visible between more experienced educators and those who had recently obtained their qualifications.

Especially research designs such as ours, with mostly qualitative data, required that we use a variety of strategies to enhance validity, including the extent to which interpretations and perceptions had shared meaning between participants and researchers (Maree & van der Westhuizen, 2007). As suggested by the latter authors, we therefore decided how we ensured that data collected was valid, for example by obtaining advice from expert researchers on the questionnaire to ensure internal validity in terms of causal inferences and by obtaining detailed descriptions of participants and their contexts for the facilitation of external validation and generalizability. McMillan and Schumacher (2001) agree that validity, especially in quantitative research, includes issues of reliability.

Maree and van der Westhuizen (2007) also indicated the triangulation already referred to earlier in this section as being critical for the facilitation of interpretive validity. We therefore ensured reliability by triangulating data and paying attention to establishing and increasing data trustworthiness.

As McMillan and Schumacher (2001) suggested that the use of mechanically recorded data, such as electronic recordings, may provide precise and comparatively comprehensive evidence, the semi-structured interviews were recorded to enhance the validity of the data collected. However, in order to produce usable data, situational features, which could influence data and may enable data interpretation, should be noted. Tangible, exact accounts from notes and discussion explanations are the characteristics of qualitative research and represent the most important technique to recognise patterns in data. Handwritten notes were therefore also made during the interviews.

**Discussion of results**

**Biographical details**

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The data collected further indicated that the seven respondents older than 36 years all had more than 10 years teaching experience, although this was not necessarily experience in teaching CAT. These same respondents also only attend short courses and workshops on how to teach CAT, while the three younger educators (less than 30 years of age) were qualified to a third year university level, specifically for teaching CAT.

**Summary of interview responses**

In their responses to the questions in the semi-structured interviews, all participants agreed that CAT is generally a rewarding subject to teach. In terms of the most rewarding parts of teaching CAT, they indicated that learners are eager to learn about new technologies. Discipline is much better in the computer laboratory due to the environment, and as the learners’ engagement is often greater when they are practically busy and interested, they do not have time to get up to mischief (Lai & Pratt, 2007).

Although they enjoy teaching CAT, there are many challenges that these educators face on a daily basis. Participants explained that some learners seem to become discouraged when they struggle with a difficult concept, and then give up easily, without trying to solve the problem. Three participants echoed sentiments expressed by Evoh (2007), that the biggest challenge that they face is that limited educational resources and infrastructure constrain their ability to cope with all the learners who would like to enrol for CAT. In most cases, there are very limited finances available for the upgrading of software and hardware, or buying ink cartridges for learners to print their assignments, tests or projects. Eight of the participants accepted the fact that they do not have adequate resources, but two of them adapted in exceptional ways to these problems - they went to private companies asking for donations. When learners did not have Internet to do their research projects, these educators arranged with a local Internet Café for a group discount, and booked the Internet Café out for a whole afternoon. These two participants also arranged for their learners to do their final CAT practical examinations at a nearby university computer laboratory. These participants, who are regarded as novice educators, based on their teaching experience, adapted exceptionally to technology changes and challenges.

Another challenge that five of the participants mentioned was the lack of time for completing the curriculum, as they feel that it is “jam-packed”. The educators find it difficult to teach, allow the learners to practise, do continuous assessment during class time, finish the Practical Assessment Task, and do revision and preparation for the examinations. The possible solution they suggested for these challenges was to reduce the continuous assessment tasks, in order to allow learners to have more time to practise new content.

Participants’ opinions about the role that experience plays when adapting to technology changes varied according to the amount of experience they had themselves. Educators with the most teaching experience felt that experience plays a big role, although they find it difficult to adapt to change. Even though they do not have many years of teaching experience, novice educators’ attitudes were that their knowledge make up for their lack of experience. They also felt that because they are younger, they adapt to change easier and that the learners understand them better.

It is interesting to note that all participants in this study confirmed results obtained in a field study by Banyard *et al.* (2006), of growing ICTs competencies amongst CAT learners, being part of the so-called digital generation. They agreed that these learners seem to cope with the
frequent technology changes as a matter of course, and that learners in their CAT classes do not have any problems whatsoever with adapting to technological change. However, educators were asked to explain what it is that they do further to make learners’ adaption to these changes even easier, and to discuss how they adapt to technology changes in their own classes. The participants mentioned that they go to trouble to avoid any obstacles that may occur during the change of applications software packages. They download examples and tutorials from the web to present to the learners. They give extra lessons to learners who might need these. The data projector is widely praised as a media source for its assistance in classes.

Contributions obtained with regard to educators’ views on using textbooks as learning and teaching support materials in CAT revealed that they regarded these positively, even though the books become out-dated so fast. Half of the participants specifically indicated that textbooks were not their only source of information, and that they use papers from previous years and self-created activities to prepare their learners for the examinations.

With regard to opportunities available to support them in adapting to change, it was heartening that all CAT educators interviewed indicated that they receive significant support from the CAT facilitator for this district in Tshwane. The facilitator was hosting workshops and cluster meetings to make sure that all the CAT educators are competent to teach the subject. Where they might lack knowledge or skills, support was being offered. All the participants were satisfied with the support they received from the Gauteng Department of Education (GDE) and their colleagues.

Finally, remarking on their attitudes, as CAT educators, towards lifelong learning, with only one exception, most participants agreed that this is unavoidable. The other participant felt that the frequent changes she had gone through (from being an educator for other related subjects, to being a CAT educator) were a hassle, and that she considered resigning from the teaching profession because of that.

Strengths and limitations of the study, and recommendations

We believe that one of the major strengths of this study is situated in the fact that we went to the trouble of trying to ensure that the range of participants not only represented the ‘typical’ demographics of a CAT educator (older white female), but also to include males, various races, ages and teaching backgrounds – this should make the findings more generalizable. The research instruments used in this study was available only in English, which is the second language of most participants in this Tshwane district, and depending on participants’ preference, the semi-structured interview was conducted in English or Afrikaans. Although it was initially feared that this would be a limitation of this study, all participants felt fairly competent, as a lot of the terminology and jargon regularly used in relation to CAT was in English.

Although some might see the limitations in terms of current research in literature available in the focus areas of this study as a weakness, we believe that it provided us with an excellent opportunity to start filling in the many gaps identified. Even though Evoh (2007) admitted that barriers to the introduction of new practices and use that need to be addressed will vary from country to country, he recommended that educators from developing world regions could learn from one another. Kozma (2005) similarly indicated that educators ought to consider combining contributing influences, which could collaboratively have an effect, particularly those related to changes in pedagogy. Mukama and Andersson (2008) agree that in order to achieve this, appropriate pedagogy in the area needs to be developed, which would allow educators to develop a critical mind towards supporting their ability to use a range of technologies and new tools to solve problems (Evoh, 2007), as also suggested by Lim et al. (2007).
The topological area where this research was carried out might place some limitations on the generalizability of findings, because it covers only a small area in the Gauteng province of South Africa. Gauteng is also the province with the best CAT results, and the outcomes of a study such as this one may therefore vary from province to province. Since this district is also fairly much located in an urban setting, educators from rural areas might have other/more challenges. Finally, we need to mention that subject advisors as referred to by the educators in this study, are usually allocated one to each district, and educators’ experiences in other districts and/or from other provinces could thus be totally different from those described here. It is therefore recommended that similar research be carried out in other districts and provinces in South Africa, possibly widening the target group so that it stretches over a bigger geographical area, and therefore have a bigger range.

Conclusions
In terms of the primary research question set for the study reported on in this paper, the main findings imply that most CAT educators in this Tshwane district readily adapt to technology changes, although it does require some effort to do so.

With regard to the role that educators’ experience play when adapting to technological changes, it is clear that those CAT educators regarded as novices (based on their number of years teaching experience) adapt easier to technology changes than their more experienced colleagues. As indicated by Lai and Pratt (2007), these novice CAT educators seem to take up more novel educational challenges, especially using ‘hands-on’ practice to adapt to change, than do the more experienced educators. Mukama and Andersson (2008) agreed that these behaviours enable novices to actively commit to becoming responsible educators.

In terms of the nature of CAT educators’ attitudes towards lifelong learning, the attitudes of the majority of participants were that lifelong learning is a lifestyle, more than a skill. In agreement with the latter authors, they assumed that outlooks such as these could demonstrate prospective parts for advancing adjustment, which have to be positive for them to not only adapt to change, but in fact to be eager to change.

Goosen (2004), however, warned that working and learning conditions needed to be created in terms of supporting educators’ work by making changes, new activities and learning possible at classroom level. It was therefore pleasant to receive feedback on the CAT educators’ stance towards their authorities at the GDE: They were all positive that the opportunities available to CAT educators, and the help they receive to support them during these changes, are contributing to making their adaption to change easier, and making better CAT educators of them.

Although such extended research would benefit the educators of the subject even further, we believe that this study has already begun to point to ways in which CAT educators’ adaption to technology changes “can be supported by an integrative framework of … professional knowledge which recognizes connections between subject domain knowledge, the didactic relation with information and communications technology … and an openness of mind in the moments of teaching” (Loveless, 2007 p509).

The importance of the study reported on in this paper is thus further justified in terms of adding to the little that is already known about this topic, by starting to fill in the many gaps, or addressing the silence in available literature, to bring greater clarity to this mainly unexplored field of study. According to Banyard et al. (2006), international assessments suggest that such experiences being investigated spans across national borders and are not sector specific. What we therefore report on in this paper in terms of the results from this
research could not only make an original contribution towards informing debate in this field, but also represents independent scholarly research.

Dedication
This paper is dedicated to a dear friend and colleague, Carol van der Westhuizen, who unexpectedly passed away in April 2011.

References


Effects of dialogical argumentation instruction in a computer-assisted learning environment on grade 10 learners’ understanding of concepts of chemical equations.

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Abstract
This study explored how Dialogical Argumentation Instruction (DAI) within a Computer-Assisted Learning (CAL) environment enhanced students’ understanding of concepts of chemical equations. In particular it focused on aspects of dialogical argumentation and whether it is applicable to the science classroom. Furthermore it investigated whether to modify, adopt or redesign existing argumentation theories to improve the learning of concepts of chemical equations. Computer Assisted Learning (CAL) was used to provide the premises to build an appropriate argumentation framework. The National Education Department encourages the use of computers and computer software in implementing outcome-based curriculum in the classroom, as stated in its e-Education policy. They argue that “South African students in the GET and FET bands should be information communication technological literate by 2013” (DoE, 2003). The Education Department aims to create new models of learning that will radically change the concept of education and the delivery of it (DoE, 2003). The Education Department is currently busy to streamline the curriculum even more by lessening the administrative burden on both educators and students by making new changes to the curriculum, in the form of the Curriculum Assessment Policy Statements (CAPS).

Another aspect of this study is to determine to what extend CAL in science is being used currently in selected schools in the Western Cape. A number of schools in the Western Cape have ICT resources. For example a high school in Kraaifontein have data projectors in every classroom. My observation has been that these are not used optimally.

Introduction
Since the introduction of computers into education, more than twenty years ago, education authorities globally have believed that it would drastically improve student performance and achievements. However, many studies have shown that the use of computers in education has not improved student performance and achievement significantly (Kosathana, 2002). Computer Assisted Learning (CAL) offers a range of different tools for use in school science namely, data capturing, processing and interpretation, multimedia software for simulation of processes and carrying out virtual experiments, information systems like the internet, intranet and CD-ROM’s, publishing and presentation, digital recording equipment and computer projection technology (Osborn, 2006).

According to Osborn these ICT 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 links 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-tools 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. The role of the educator and the computer is to mediate the learning process and be a co-constructor of knowledge (Vygotsky, 1979).

The objectives of the National Education Department’s to have most learners information communication Technological literate by the year 2013 and that new models of learning should also be created to improve curriculum delivery in schools (DoE, 2003) if the education departments and service providers provide the resources and training within an appropriate methodology. The concerns of scholars like Farrell (2007), who states that, “Although computers can play a positive role in the teaching-learning process, the pedagogical environment must be conducive.” should also be taken serious. Dialogical Argumentation Instruction (DAI) provides the necessary atmosphere within which students can acquire new learning and communication skills, rectifying erroneous concepts and broaden their worldview. Generally learners find it very difficult to master chemical equation concepts which are one of the fundamental bases of chemistry in physical sciences. Outcome-Based Education (OBE) emphasises that the learning process should be learner-centred and that physical sciences is enquiry based in particular. The Specific Outcomes stresses that learners should be developed into productive critical thinking citizens. This is in contrast to the Apartheid education methodology prior 1994 which forced learners to be passive receivers and teachers to be transmitters of knowledge.

The results of systemic testing (ANA) of 2011, which was conducted throughout the national education schooling system, in which learners are tested at different grades of the FET and GET bands, indicated that learners struggle with science and mathematics learning areas. This study objective of this study is to firstly determine the status quo of Information Communication Technology (ICT) resources and the use thereof in selected schools and secondly to determine how do grade ten learners exposed to Dialogical Argumentation Instruction (DAI) demonstrate a better understanding of chemical equation concepts, than those not so exposed.

Theoretical framework
This research study is underpinned by theories of Toulmin (1958), the Toulmin’s Argumentation Pattern (TAP), and Ogunniyi (2007a), the Contiguity Argumentation Theory (CAT). The TAP investigates the inductive-deductive processes in a discourse, while the CAT recognises and reconciles the interaction between different worldviews and cognitive states. The CAT also reaches beyond the TAP, because besides explaining the inductive-deductive processes it also explains metaphysical processes. The constructivist theories as espoused by Vygotsky and Piaget in which they explain the ways how learners construct their own knowledge are also used. These different theoretical models together with computer assisted learning (CAL) are used to support the instructional intervention – Dialogical Argumentation Instruction (DAI).

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 educators to enhance educators’ and students’ understanding of 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. TAP argumentations in the classroom discourse can be classified into seven levels of argumentation, from level 0, which is a non-oppositional argument to level 6, which involves arguments with multiple rebuttals challenging the claim and / or grounds.

Figure 1 illustrates the TAP process and Figure 2 give an example of the different elements of the TAP process. Claims – these are assertions (declarations without support) about what exist or values that people hold. Data – these are statements that are used as evidence to support the assertion. Warrants – these are the statements that explain the relationship between the data to the claim. Qualifiers – these are the specified conditions under which the claim holds true. Backings – these are underlying assumptions which are often not made explicit. Rebuttals – these are statements which contradict the data, warrant, backing or qualifier of an argument. Counter-claims – these are simply opposing assertions.

**Fig. 1: Toulmin’s Argumentation Pattern (Toulmin, 1958)**

The man is a British subject. **Claim**

A man born in Bermuda will generally be a British subject. **Warrant**

Both his parents were aliens/become naturalised American citizens. **Qualifier**

The man was born in Bermuda. **Data**

**Fig. 2: Elements of Toulmin’s Argumentation Pattern (Toulmin, 1958)**

Contiguity Argumentation Theory (CAT)
The Contiguity Argumentation Theory (CAT), which dates back to the Platonic and Aristotelian era, is a learning theory which states that more than one distinct thought system
can co-exist and that there is a flexible movement between the cognitive states as explained by Ogunniyi (2007a). The CAT recognizes five categories into which conceptions can move within a student’s mind or amongst students involved in dialogues justifying scientific and / or IKS-based conceptions. 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 believe 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.

**Methodology**
The research site was a school which is well-known for producing good grade twelve results. In the past four years the grade twelve overall results was in 2008 sixty per cent, in 2009 it was fifty-two per cent, in 2010 it was sixty-seven per cent and in 2012 it was eighty-three per cent. The physical sciences maintained an average of fifty per cent over the past four years. The reason for the lower performance in terms of the over grade ten pass rate is because the majority of the science learners do mathematical literacy, which do not support some important mathematical concepts which is crucial in physical sciences.

This study is located within the interpretive paradigm in which the researcher tries to understand the behaviour of the participants with in their context. A sequential mixed method was used in which the study elaborates and expands on the quantitative data findings qualitatively (Creswell, 2009). The quantitative method entailed a quasi-experimental design to measure the differences between the conceptual understanding of the experimental and control group. The following format was used for the quantitative design:

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O₁ (pre-test) and O₂ (post-test) was the experimental group (E) that was subjected to an intervention, x, which is the Dialogical Argumentation Instruction. O₃ (pre-test) and O₄ (post-test) is the control group (C) which was not subjected to Dialogical Argumentation Instruction. However, both groups was subjected to the use of Computer Assisted Learning.

**Data collection and analysis**
Data collected from the ICT resources survey was used to get a general idea of the extent to how schools in the vicinity are equipped with ICT resources. The data from the interview and classroom observation schedules was classified (coded) and use to give a subjective description of the social background of the students and the conditions of the school and the classroom. The results of the Chemistry Achievement Test were used to determine the improvement and difference in the conceptual understanding in the experimental and control groups. The Chemistry Achievement Test was marked with marking memorandum
and analysed for conceptual changes, misconceptions and trends of argumentation of the respondents. The questionnaires on attitudes towards science (AtS) and the teaching styles (TS) was qualitatively analysed to put the scores of the learners into a broader perspective. SPSS computer software was used to compare mean scores, t-ratio and compare with t-critical values in the quantitative analysis of the data.

Samples
The ten schools for the ICT resources survey was randomly selected form twenty high schools of two circuits in the Education Metropol District (EMDC) North, Western Cape Education Department. The experimental and control group was grade ten classes at the school of the researcher. The experimental group initially consist of 30 learners and the control group 28 learners. Eventually both groups were reduced to 25 learners due to attrition.

Why the two groups at the same school?
The majority of the learners come from different areas of Cape Town; Bellville South, Belhar, Kuils River, Delft, West Bank, Eerste River, Mitchell’s Plain, Khayelitsha, Nyanga and Kraaifontein. At the end of the school day the learners rush for their transport home, they travel either by private transport, busses or trains. There will almost be no time for subject to interact. Secondly the subjects of the experimental group have English as home language and the control group have Afrikaans as home language and usually learners with different home languages do not associate. Thirdly the groups have different subject choices; the experimental group has more academic subjects whereas the control group has technical subjects, thus they most probable have different interests and hobbies which will make it more unlikely that they will associate.

Subjects selections
The two groups were selected out the of four grade ten physical sciences classes, who completed the pre-test, at the research school on the basis of different home languages and subject choices to minimise contamination. Another reason was because the scores they score similarly in the pre-test. The objective and process of the research project was explained to all the subjects and they were given consent formed which their parents completed.

The Hawthorne effect
Hawthorne-effect, which state that if subjects are aware that they are being studied, they do not behave normally (Dowling and Brown, p.46), would have influence the outcome of a study. Therefore the results of this study may not be entirely attributed to the intervention, because the subjects are aware that they are part of a research process. In addressing the Hawthorne effect and other extraneous factors like, extra classes, access to resources at home, etc., the groups was treated in the same period of time and different languages.

Training of subjects in terms of TAP
The researcher was inducting the experimental group in the practice of dialogical argumentation during the first and second term of the year. The subjects were excited to be part of the research project, especially when it comes to group work and argumentation. However the over-eagerness and excitement led to the fact that learners often stray of the point of discussions and control problems. The researcher had to put down strict house rules and protocol for group work and argumentation.

Validity and reliability of instruments
Validity of instruments is obtained by the triangulation of the data gathered with the different tools. The Cronbach’s alpha reliability test was used for the instruments and a reliable index of .765 was calculated. All the instruments was evaluate and ranked by a group of expert science teachers at the School of Science and Mathematics Education at a university in the Western Cape. The Chemistry Achievement Test as piloted at two schools and adjusted to address the research questions effectively.

The chemistry achievement test

Section A
This section covered prior and basic knowledge of chemical species like atoms, molecules, compounds, ions, etc. Learners were presented with three dimensional models to give them an idea of the spatial orientation in terms of shape and size as indicated in the figure 3 below.

![Fig. 3: 3D ball-and-stick model of the water molecule (www.sciencephotolibrary.com)](SCIENCEPHOTOLIBRARY)

Many grade 10 learners have difficulty to visualise the relative size differences and orientation of different chemical species (ions, atoms and molecules), they are supposed to have some knowledge of the particulate nature of matter, because in grades eight and nine they are exposed to the kinetic theory of matter (KTM) and the periodic table. In grade ten learners are expected to have a good understanding of the KTM and they are introduced to the historical development of the atomic model from the very small indivisible particles, according to Leucippus and Democratus in 440 BC, to the electron clouds of Schrödinger (Kelder, 2011), electron configuration and the periodicity of the periodic table.

Section B
This section takes it further and focuses on the different chemical bonding, covalent bonding, ionic bonding and metallic bonding and the processes involve in each. Computer software animations and models was used during the activity sessions to give the learners a better understanding of the complex processes involve. Figure 4 is a screenshot of an illustration showing the movement of electrons around the nuclei of two hydrogen atoms. The colourful animation gives the learners an inside view of the models of the atoms. Learners could easily conceptualise the inside of an atom during covalent bonding, which would be difficult to explain in words.
Similarly does another animation of the covalent bonding of the water molecule in figure 5 below. It indicates the polarity of the dipolar water molecule.

The presentation of chemical reaction by means of 3D-models and animations is very useful. In grade eleven the learners go deeper into the chemical bonding process by studying more complicated aspects of electrostatic forces between subatomic particles, the arrangements and re-arrangements of electrons in terms of the valency electron repulsion which is responsible for the polarities of molecules, molecular shapes and orientation and the intermolecular forces. These aspects also lay the basis for the introduction into organic chemistry.

Figure 6 shows the animation of the process of ionic bonding of sodium chloride. What is interesting is the fact that it shows both the macroscopic and the microscopic views of the bonding process. This is useful especially in the unavailability of apparatus and the danger
involves in conducting the actual experiment practically, sodium is a very reactive metal and chlorine is a very poisonous gas. The animation also highlights the different in sizes of the particles (atoms, ions, electrons, protons and neutrons)

Figure 6: Screenshot of the animation of ionic bonding of sodium chloride (www.visionlearning.com)

Figure 7 shows the “sea of free” electrons moving between the positive metal ions when there is a potential difference across a conductor.

Fig. 7: Screenshot of the animation of the metallic bonding in copper (www.visionlearning.com)

Section C
This section focussed on the writing of formulae, balancing of chemical equations and the principle of conservation of mass. Learners was showed how molecules react to form products by means of simulations. Figure 8 shows a screenshot of the electronic worksheet which learners used to balance chemical equations, the worksheet automatically mark and give feedback to learners. This was done after the learners were introduced and familiirised with the rules of writing formulae and balancing equations. following the rules and also check their answer.
This section provided learners with everyday examples of chemical reactions. Learners had to identify the chemical substance and formulae in order to write the correct balance equations for the chemical reactions. Here the chemistry was made more relevant to everyday experiences of the learners. The scenarios used referred to swimming pool acid (HTH), heart burn, acid rain, baking of bread and food preservation.

Ethical considerations
The respondents were kept anonymous and all participants of this study were informed about the final report of this research. Western Cape Education Department (WCED) granted permission and ethical clearance to conduct research in the selected schools. Parents did give all the consent forms of the subjects. Fair treatment of the groups in terms of making use of information communication technology and content was given, because all subjects did receive the same learning material and had equal access to the ICT resources.

Results and discussion
In addressing each of the research questions, the results was firstly quantitatively analysed by making use of non-parametric statistics, because the subjects were not randomised and did not always give a normal distribution curve. The data and results was also qualitatively analysed by describing the research setting and conditions in order to make meaningful conclusions.

The intervention - argumentation
The simplified levels of argumentation according to TAP, in table 1 below, was used to determine the nature of argumentation reached in the lessons in the experimental group.
### Table 1: Simplified levels of argumentation according to TAP

<table>
<thead>
<tr>
<th>Quality</th>
<th>Characteristics of an argumentation discourse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>Non-oppositional, only claim/statement (yes or no answer).</td>
</tr>
<tr>
<td>Level 1</td>
<td>Argument involves claim/statement with single motivation/reason/ground no rebuttals.</td>
</tr>
<tr>
<td>Level 2</td>
<td>Argument involves claim/statement with more than one motivation/reason/ground no rebuttals.</td>
</tr>
<tr>
<td>Level 3</td>
<td>Argument involves statements/claims or counterclaims with motivation/grounds/evidence and rebuttals.</td>
</tr>
<tr>
<td>Level 4</td>
<td>Argument involves multiple rebuttals challenging the claims and grounds</td>
</tr>
</tbody>
</table>

Modified after Erduran, Simon and Osborne (2004)

The original seven levels of argumentation according to Erduran (2004) were reduced to four, because the learners have been exposed to the dialogical argumentation instruction for a short period. The learners were in the initial stage of argumentation; during which most of them only reached argumentation level 3. No learner or group did reach level 4 where the argumentation process is involving intense exchange of claims and rebuttals.

**The status quo and use of Information Communication Technology (ICT) resources in selected schools.**

**Graph 1: ICT resources and use thereof at the selected schools in terms of percentages.**

One can conclude from the data in the graph that all the school have at least basic ICT resources, but it is not used optimal in the science classroom. Various reasons could be attributed to this observation. Some of the responses science teachers gave to the question, “Why are the ICT resources not used optimal?” were:

Teacher from school 2: The content laden curriculum does not allow time for learners to work on the computers in the classroom, than I will not be able to finish the work in time.

Teacher from school 4: Although the science learners must also use the computer laboratory of the school, it is always a fight with the CAT teacher to get a turn.
Teacher from school 5: I never got training to use the software on the computers; I only use the interactive white board to give notes to the learners.

Teacher from school 8: Our software are outdated and the licenses expired long time ago. The principal do not want to give money to update and renew the licenses.

These responses indicate that problems such as ICT-insensitivity of the curriculum, access to ICT resources, ICT training and maintenance of ICT resources are stumbling blocks for science teachers to effectively use ICT in the science lessons. On the question whether the use of ICT resources could improve the conception and performance of science learners, some of the teachers responded as follows:

Teacher from school 1: Learners seems to understand concepts in chemistry much better and quicker when they saw the animation model of it, than when I explain it to them.

Teacher from school 2: Learners understand the workings of the computer better than I do, so something I just let them work on the computer in groups and report back to the class. You will be surprise how quickly they understand the work.

Teacher from school 6: I let them work through PowerPoint presentations that I used in class, and let them complete worksheets at home or after school. This safes lot of time.

Teacher from school 9: Some software cover aspects that I normally would not do in class, this gives the learners a broader understanding of the work.

It is evident from these responses that the science teachers feel that ICT can contribute positively to the teaching and learning process, in terms of explaining difficult concepts, safe time, working at their own pace, collaborative learning, etc.

Do grade ten learners exposed to dialogical argumentation instruction (DAI) demonstrate a better understanding of chemical equation concepts, than those not so exposed?

Qualitative findings of the Chemistry Achievement Test
The results was obtained statistically by making use of the Mann-Whitney U Test for independent samples as well as the Wilcoxon signed rank test for comparison of the results for each group. The table below gives a summary of the learners’ pre-test and post-test results obtained for each item in the Chemistry Achievement Test.

<table>
<thead>
<tr>
<th>Item</th>
<th>Group</th>
<th>t-value</th>
<th>Between group significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Prior knowledge of molecules</td>
<td>Pre-test</td>
<td>0,97</td>
<td>0,341</td>
</tr>
<tr>
<td></td>
<td>Post-test</td>
<td>1,20</td>
<td>0,237</td>
</tr>
<tr>
<td>2. Chemical bonding</td>
<td>Pre-test</td>
<td>0,51*</td>
<td>0,610*</td>
</tr>
<tr>
<td></td>
<td>Post-test</td>
<td>3,05</td>
<td>0,004</td>
</tr>
<tr>
<td>3. Balancing of equations</td>
<td>Pre-test</td>
<td>0,11</td>
<td>0,910</td>
</tr>
<tr>
<td></td>
<td>Post-test</td>
<td>1,23</td>
<td>0,225</td>
</tr>
<tr>
<td>4. Everyday scenarios</td>
<td>Pre-test</td>
<td>0,33</td>
<td>0,740</td>
</tr>
</tbody>
</table>

241
Comparing the groups before the study
The pre-test results show that the difference between the mean scores and the standard deviations for the experimental and control groups are very small. The t-ratio value of 0.44 is less than the t-critical value of 1.71, which indicates that the null hypothesis which expects significant differences between the groups can be rejected. Therefore it can be assumed that there was no statistical significant difference between the groups at the pre-test, suggesting the comparability of the two groups at the beginning of the study. However it can be assumed that both groups have some measure of knowledge of chemical equations, because both groups scored an average of 20 out of 60 for the pre-test.

Pre- and post-test score of the experimental group
The null hypothesis which expects no significant differences between the pre- and post-test of the experimental group is rejected, because the t-ratio value of 6.56 is greater than the t-critical value of 1.71. This indicates a statistical difference between the pre- and post-test results of the experimental group. The t-test results indicates a significant change in the means of the pre-test and the post-test, thus it is safe to assume that experimental group did improve their conceptions of chemical equations considerably. It can be assumed that the improvement can be attributed to the argumentation instructional strategy that the group received.

Pre- and post-test scores of the control group
As in the case of the experimental group, there is a significant difference (t-value = 4.04 and t-critical = 1.71) between the pre- and post-test scores of the control group. Thus, the traditional instructional method used in the control group did also produce an improvement in the performance of the group, but to a lesser extent than observed in the experimental group.

Comparing the groups after the study
When comparing the post-test results of the experimental and the control group, the t-ratio value is greater than the t-critical value, thus the null hypothesis which is expecting no significant difference between the two groups is rejected. This indicates that the argumentation instructional method used in the experimental group is more effective than the traditional method of instruction used in the control group. The differences in the mean percentages between the pre- and the post-tests for the experimental and control groups respectively are 29.07% and 14.93%. Although the experimental group outperformed the control group by 15.40%, it is worthy to notice that the control group improved with 14.93% from the pre-test to the post test.

Qualitative findings of the Chemistry Achievement Test
Question 1
“Are the size of the atoms correctly presented in the diagram (water molecule with all the atoms the same size, refer to figure 1)”, the following responses were given:
### CLAIM | EVIDENCE | WARRANT
--- | --- | ---
**Pre-test responses**
C13: “Yes, all atoms are microscopic small.” | None | None
E5: “Yes, they are the same size, because all the atoms of all elements are identical.” | “…because all the atoms of all elements are identical.” | None

**Post-test responses**
C13: “No, O-atom is bigger than the H-atom, because the O-atom has more orbitals and energy levels.” | “…because the O-atom has more orbitals and energy levels.” | None
E5: “No, they are not the same size, because the O-atom is bigger than the H-atom, because the O-atom has more electrons than the H-atom.” | “…because the O-atom is bigger than the H-atom …” | “…the O-atom has more electrons than the H-atom.”

In the pre-test both respondents provide invalid responses, but in the post-test they gave valid responses. Learner C13 gave a level 2 response (single motivation) and learner E5 gave a level 3 response (single motivation and a warrant). Both learners moved to an emergent cognitive state, because they were introduced and internalised new concepts.

#### Question 2
“What type of chemical bonding takes place in the formation of table salt? Explain the bonding process.”

These learners show a positive shift in their conceptual understanding from the pre-test to the post-test stage. In the pre-test learner E5 gave an invalid response and has the misconception that all atoms are identical in size. All atoms have the same have the same configuration, but differ in the number of subatomic particles from element to element. However in the post-test she provides a valid response which includes a backing and a warrant.

<table>
<thead>
<tr>
<th>Pre-test responses</th>
<th>Post-test responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>C3: “It is ionic bonding. Electron transfer takes place between the sodium and the chlorine atoms.”</td>
<td>“…the Na-atom gives away an electron, which is accepted by the Cl-atom to form the NaCl-crystal.”</td>
</tr>
<tr>
<td>E6 “It is ionic bonding, because sodium chloride is formed by vaporing water from sea water.”</td>
<td>“…the Na-atom donates an electron and becomes a Na⁺-ion. The Cl-atom accept the released electron and becomes a Cl⁻-ion. Therefor the positive ion and the negative ion attract each other because of electrostatic forces between them and form an ordered arrangement of negative and positive ions.”</td>
</tr>
</tbody>
</table>

Learner C3 shows improvement in his understanding of the ionic bonding process by elaborating on the electron transfer between the atoms. The pre-test backing of learner E6 is invalid, because it refers to a physical change. In her post-test response she provide evidence (…because a Na⁺-ion donates …becomes a Cl⁻-ion.) and also gives further backing by referring to the electrostatic forces between the ions.
Question 2d
“What type of chemical bonding is found in the silver teaspoon? Explain why the handle of a teaspoon feels hot after a few seconds when put in hot tea.”

<table>
<thead>
<tr>
<th>Pre-test responses</th>
<th>Post-test responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>C15:“It is metallic bonding. Heat diffuses from hot to cold areas.”</td>
<td>“…the teaspoon is a metal and metals are good conductors of heat.”</td>
</tr>
<tr>
<td>E20:“It is metallic bonding. The stream of the tea made the teaspoon handle hot.”</td>
<td>“… The teaspoon’s handle become hot because of the loose [delocalised] electrons that are given energy by the hot tea making vibrating faster and bump into the colder loose electrons. Therefor the handle becomes hot.”</td>
</tr>
</tbody>
</table>

Learner C20 made a valid claim, but do not give a backing supporting the claim. Learner E15 demonstrates a misconception about diffusion (movement of gas particles) in the pre-test, but in the post-test he gives backings, evidence and warrants. Learner C22 provide a valid counter claim with a backing.

The experimental group and the intervention
The class was divided into six groups of four learners per group. Learners had to firstly complete the worksheet individually before the individual responses was shared and discussed in the group. Each group choose a group leader how facilitate and make sure that maximum participation takes place.

Classroom observation in the experimental group:
In the experimental group the teaching process were more learner-centred. The sessions were normally start with the teacher eliciting prior knowledge from learners before introducing the new topic for the first ten minutes. In the following ten minutes learners was given worksheets to complete individually. Thereafter learners moved into their groups where they shared and discussed their individual answers and responses. Within their groups they deliberated and interrogated the individual inputs and reach consensus on the answers. In the last ten minutes of the period the groups represented their findings to the class and a whole-class discussion follows. At the end the teacher summarised the different groups’ findings, highlighted the misconceptions and erroneous concepts that was picked up and reinforced the intended learning objectives.

Classroom observation in the control group:
In the control group the teaching process was quit rigid predictable. The teacher introduced the topic for about ten minutes, hand out an activity sheet which the learners completed individually for about twenty minutes, while the teacher walked between the learners and assisted those learners who seemed to be struggling with the activities. During the last ten minute he wrote the answers of the activities on the chalkboard and the learners have to correct their own answers. When time permitted the teacher did entertain a few questions from the learners. It was also obvious how teacher-talk dominated learner-talk in these sessions. The teacher was talking for 19 minutes, learners for 8 minutes and no talk for 13 minutes for the period of 40 minutes. Like in the case of the experimental group, there was a significant difference between the pre- and post-test scores of the control group. Thus, the traditional instructional method used in the control group did also produce an improvement in the performance of the group, but to a lesser extent than observed in the experimental group.
Conclusion
In terms of the global picture South Africa perform poorly with regard to education, even compare to the countries on the African continent. The renewed effort of the South African government to invest and promote science education in the light of the mega technological projects such as SALT and SKA steer the country in the correct direction. This study found that the experimental group did benefit from the argumentation methodology. It is important that education instructional methodologies should be adopted to improve the performance of learners optimally. Argumentation-based instruction (TAP) must form an important part of science education, because science is based on enquiry and problem-solving strategies, which is key elements of DAI.

References
Making educators’ use of virtual learning environment tools relevant for open distance learning across Africa

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Abstract
The purpose of this study was investigating research questions around educators’ use of Virtual Learning Environment (VLE) tools, justifying importance and relevance for Open Distance Learning across Africa. Latest research results on the generation of learners we are teaching, their learning styles and needs are presented. Our literature review continues over-viewing the VLE, followed by the extent to which learners use it. Educators’ adoption of new technologies is also interrogated. The study is located within a relevant conceptual framework that clarifies issues around a selection of the tools available within the institutional VLE. Methodology described attends to the importance of interpretation for qualitative parts of research design and considers issues of reliability and validity for quantitative designs. Both quantitative and qualitative results are discussed, providing insight into educators’ responses - these are in some instances connected back to literature. We indicate the possible implications of our results for other educators and make recommendations about how these could be applicable and useful for them. In conclusion, results are organised to answer the original research questions posed, we reflect on how our results make an original contribution towards scholarly debate in the field and identify options for further research.

“Our vision is to become Africa’s premier distance education provider, serving every country on the continent and transcending language and cultural barriers” - University of South Africa.

Introduction
VLE … Is there a Very Large Elephant in the room that some are just trying to pretend that it doesn’t exist? Is the Very Large Elephant a white one, that no-one seems to have any use for? Or is it a Very Luxurious tool for Entertaining learners?
The Virtual Learning Environment (VLE) used at the University of South Africa (Unisa) is known as myUnisa, while other institutions across Southern Africa implement similar systems such as eFundi (North-West University) and ClickUP (University of Pretoria) - most universities have adopted a number of technologies within these environments to facilitate learning. However, the available technologies are not always implemented equally throughout the various colleges/faculties, schools and/or departments (Cant & Bothma, 2010).

The research questions around which we centred our inquiry therefore asked educators from the School of Computing (where both authors are located) to shape the first of their responses around whether they felt that their active participation on myUnisa had them see any difference in their learners’ performance, and/or did their learners’ pass rates improve? They were also queried about the possible value they got from using one or more particular tool(s) - Did it make any difference / was it beneficial in their teaching of their modules? Finally, they were requested to share their reflections on what they thought of the whole process around their use of the various myUnisa tools to teach / deliver their modules.
Whereas an article by Mbatha and Naidoo (2010) set out to investigate the use of myUnisa as the Unisa e-learning forum from a learner perspective, the purpose of our research was to explore the viewpoints of educators. Similar to that of Hart (2008), our research interrogates these related to the contexts of educators’ day-to-day experience with different tools in this environment, to ascertain the influence these might have on their ability to effectively implement these technologies. The importance of this paper is justified in terms of the contribution it could make towards the encouragement and increased use of different VLE tools by educators (Mbatha & Naidoo, 2010). Along with De Hart et al. (2011), we acknowledge that not all results obtained in this way can necessarily be addressed in an academic program, but the results of the study could potentially make recommendations to assist educators in improving the throughput rate of learners.

In order to achieve this, the remainder of this paper is organised by starting to draw on the latest and most relevant research results on the topic, with a look at the so-called Net Generation of learners. Our review of literature continues with an overview of the myUnisa VLE, together with a discussion of a selection of the tools available. This is followed by a brief subsection on an indication of the extent to which learners make use of myUnisa. Literature relevant to the topic of educators’ adoption of new technologies is also interrogated. The study is then located within a relevant theoretical and conceptual framework that clarifies issues around a selection of the tools available within the institutional VLE. The research design and execution of the methodology used is outlined, in terms of describing the importance of interpretation for qualitative parts of the research design and considering issues of reliability and validity for quantitative designs. Both the quantitative and qualitative results obtained are described and discussed, providing insight into participants’ responses - these are in some instances connected back to literature. We indicate the possible implications of our results for other educators and make recommendations about how these could be applicable and useful for them. In conclusion, results are organised to answer the original research questions posed. Finally, we reflect on how our results make original contributions towards scholarly debate in the field and identify options for further research.

Literature review

Net Generation Learners

In 2010, the learner profile in the College of Science, Engineering and Technology of Unisa, under which the School of Computing falls, consisted of 58.2% learners between the ages of 25 and 39 years. According to Barnes et al. (2007), this profile is consistent with the so-called Net Generation learners. They learn in different ways from their predecessors, since they grew up with digital and cyber technology. Hart (2008) pointed out that these learners had grown up with the Internet and make intensive use of it in everyday life - he established that people in the group similarly aged 25-34 are normally very computer savvy and virtually constantly have Internet access.

These learners consciously choose in favour of learning techniques that suit them best, including doing most of their reading online, and this generation therefore needing interactive environments (Barnes et al., 2007). They show a preference for working collaboratively in groups, as relationships drive their learning processes and for them, social interaction is important for learning.

Although, according to Barnes et al. (2007), challenges related to evolving pedagogy for meeting the needs of these Net Generation learners can appear to be daunting, Hart (2008) urged educators to adjust communication delivered to these learners accordingly.
The myUnisa VLE
Khumbula and Kyobe (2011) believe that Information Communication Technologies (ICTs) have the capacity to bring about transformation in the teaching and learning processes. Heydenrych and Louw (2006) agreed that especially the so-called third generation technologies are known for their approaches that facilitate learning through interactive communication between educators and their learners (Cant & Bothma, 2010). In a similar vein, an article by Mbatha and Naidoo (2010) examined myUnisa as an educational tool for transformation, which could collapse the ‘distance’ between learners. According to Khumbula and Kyobe (2011), ICTs can play an indispensable part to enhance learners’ understanding and critical thinking when they share knowledge. Many institutions are therefore embracing such technologies.

Since their study found that using myUnisa greatly improved learners’ performance, De Hart et al. (2011) suggested that all related technologies, which could even moderately address barriers related to studying at an Open Distance Learning (ODL) institution, should be adopted by Unisa. As an e-learning resource, myUnisa has been developed by the university to supplement and enhance educator interaction and improve communication between Unisa and its learners, as well as provide an opportunity for engagement among learners. As a technology, it therefore plays an important role in facilitating learning at this higher education institution, by improving its services to learners for ensuring a seamless learning environment (Mbatha & Naidoo, 2010).

Learners’ Use of myUnisa
In terms of meeting the needs of all learners in developing countries like South Africa, Ferreira and Venter (2011) believe that technologies as described need to be incorporated into teaching and learning. The purpose of the research they conducted was investigating different likely barriers to learning that learners in an ODL situation might experience, in order to attend to these via teaching and learner support. When learners in that study were queried around their preferred mode of contact with educators, only 14% of them indicated their main preference as myUnisa. When indicating their preferred form of notification that they would like to receive around their studies, again only 11% preferred myUnisa. However, more than a quarter of respondents (28%) prefer to submit their assignments via myUnisa. Van den Berg (2011) indicated that learners are being encouraged to use myUnisa for sharing and exploring their thoughts, feelings and experiences online with others. However, Mbatha and Naidoo (2010) are of the opinion that learners are only using myUnisa to satisfy their basic educational needs. However, these authors are concerned that the VLE is not being used by educators for the intended purpose: to overcome the ‘distance’ to ensure improved engagement between learners across Africa.

Educators’ adoption of new technology
Cant and Bothma (2010) agree with Venter and Prinsloo (2011) that while ample reasons can be found to increasingly implement and manage a range of appropriate learning technologies for enhancing effective support that learners are offered, relationships between technology adoption and success are less certain. According to Ssekakubo et al. (2011), some of the probable failure causes in terms of learning management systems (LMS) supporting learning delivered fully online included high computer illiteracy amongst learners, low technology comfort levels, usability issues related to institutional LMS and inadequate user/technical support.
The study performed by Cant and Bothma (2010) showed that educators in their department did not support the active use of myUnisa. These authors state that the reason for educators’ lack of interest could be that although particular learning technologies might officially be endorsed by Unisa, it is ultimately educators who decide how much and how effectively these technologies are being used. Another reason why some educators may fail to, or are restrained in their use of, these technologies when teaching could be related to them being ‘technologically challenged’ - however, generally speaking, this is an unlikely scenario in the School of Computing.

The latter authors also mentioned that educators were not adequately informed regarding the technologies available, and might therefore be influenced to choose what appears to them to be relevant technologies, while they don’t completely understand these technologies. Their study revealed that educators were simply being expected to comply with the new learning technologies being adopted and implemented within the broader Unisa context. These authors go on to explain that this type of ‘top-down approach’ doesn’t lead to educators using these learning technologies: their respondents thought that these technologies interfered with and limited their teaching activities, or didn’t meet their requirements.

Heydenrych and Louw (2006) referred to institutions that had tried online learning, but had failed. They believe that in such cases it is important to understand how technology could have been used to assist in the core business of these institutions, as well as to respond to the market concerned - in most instances, their learners. They further remarked that although the pressures related to implementing these technologies might be high, institutions seem to be slow in developing policies related to properly supporting delivery when using new ICTs.

**Theoretical and conceptual framework**

In this section, we will now proceed to locate our study within a relevant theoretical conceptual framework. In terms of both educators and learners, Du Plessis *et al.* (2011) implemented socio-constructivist and situated learning theories within a theoretical framework for evaluating learning.

**Additional resources**

Since Barnes *et al.* (2007) indicated that Net Generation learners want to choose between various resources for creating learning experiences that are both personalised and meaningful, educators can make different learning material related to their module available to learners online in the Additional Resources tool. Learners can then access and download these materials to supplement their studies. For instance, De Hart *et al.* (2011) suggested that educators could prepare a list of basic terms to add to the Additional Resources on myUnisa - these would be aimed at facilitating learners’ understanding of the subject context. However, it does not bode well for convincing educators to use this tool when Mbatha and Naidoo (2010) reports in their study that none of the more than 100 learners surveyed ever engaged with these!

**Announcements**

The Announcements tool provides educators with the means to post announcements to all learners registered on myUnisa for a particular module. De Hart *et al.* (2011) underlined that educators could avert anticipated problems by distributing announcements related to the study material content to learners. When learners commented on engaging with myUnisa’s announcements in the study by Mbatha and Naidoo (2010), all indicated either very high (79%) or high (21%) interaction with this tool.
Blog
Barnes et al. (2007) discussed several characteristics of Net Generation learning styles, such as them needing instant gratification and independence, and wanting to be involved in the learning process. One of the ways that can be employed is by using educational strategies that use technology to learn by doing: Using blogs not only involves these learners through the Internet, but also focuses on building on their social relationships. According to Cant and Bothma (2010), such blogs can be used by educators for a variety of purposes. These are usually utilized to provide commentary or news on a particular topic, such as learner news or activities around the study material. It can also be used more personally as an online diary.

Calendar
The Calendar tool is sometimes also referred to as the Scheduler. This tool normally displays examination and assignment dates. If learners find discrepancies in the dates as it appears in their tutorial letters, they are requested to contact the responsible educators to inform them about these. Educators can also publish additional dates for e.g. tutorial sessions and other types of interactions here.

Discussion forums
Ferreira and Venter (2011) proposed the implementation of technologies such as discussion forums via VLEs in order to provide new options related to ODL support. The Discussion Forum is an excellent tool to use in assisting and supporting especially such learners, by providing them with the opportunity to form a learning community that is so often lacking in an ODL situation.

The Discussion Forum tool aims to offer an engagement forum between learners, as well as between learners and educators (Mbathe & Naidoo, 2010). It has a general category where learners can talk to their fellow learners about the module and their studies in general. They can also create their own forum topics. According to De Hart et al. (2011), learners can also use these discussion forums to obtain feedback from one another. Educators might use this tool in a variety of manners, including choosing to add topics to this forum or adding additional forums with various topics - Van den Berg (2011) suggested that educators can use discussions on myUnisa to encourage learners’ development of abilities related to critical reasoning.

Mbathe and Naidoo (2010) highlighted that learners’ participation in discussion forums is important, since it could potentially create meaning during this learning process. Malik (2010) confirmed that learners’ subjective feedback indicated the high levels of benefit that they gained from their participation in discussion forums. Learners are therefore especially encouraged to communicate their experiences, swap thoughts and debate their reactions online with other learners (Van den Berg, 2011).

While the latter author sought to obtain some indication of the impact of such online discussions through myUnisa, Mbathe and Naidoo (2010) aimed to establish the extent of learners’ participation in discussion forums on myUnisa. They found that one of the factors to which the fact that the majority of learners don’t participate in discussion forums could be attributed to relate to some learners lacking the skills they need to participate - this is in sharp contrast to the claim by Malik (2010) that all learners used the discussion forums.
Drop Box
The Drop Box tool is an electronic post box. Educators and learners can post documents to each other. Only the learner and the educator have access to this drop box.

FAQs
Cant and Bothma (2010) indicated that the frequently-asked questions (FAQs) tool can be used to answer the typical questions often asked by learners. If the FAQs tool is available on their module toolbar, learners are requested to check whether their question is not answered there before they contact educators.

Learning units
Barnes et al. (2007) demonstrated some of the ways in which multimedia resources could appeal to Net Generation learners. Educators could use such technologies and multimedia appropriately to involve their learners in autonomous learning activities. This can be done by uploading interactive courseware onto the Learning Units tool, which is the multimedia part of a myUnisa module site. In this tool, learners can then view e.g. PowerPoint presentations or digital pictures (Barnes et al., 2007). As an example, Van den Berg (2011) used a mix of media to explain to learners the impact that e.g. pictures posted on myUnisa could have.

Podcast
According to Cant and Bothma (2010), podcasting refers to the use of short audio clips (or videos, in which case it is also known as vodcasting), which are delivered to learners via their iPods, smart/multimedia phones or online.

Self-assessment
Net Generation learners need self-directed learning opportunities and multiple forms of feedback (Barnes et al., 2007). They tend to expect immediate answers, as their use of the Internet has taught them to anticipate instant access to information. The self-assessment tool allows such learners to answer mostly multiple-choice (MCQs) type questions, and then to obtain immediate answers as to whether they got it right or wrong (Cant & Bothma, 2010; De Hart et al., 2011).

Wikis
According to Barnes et al. (2007), the use of wikis represents a related use of technologies to accommodate Net Generation learning styles as much as blogs. As Wikis are ideal for working together, these are increasingly being used as collaborative writing spaces by educators. The Wiki tool provides open-editing websites where any learner or educator that has access, can add, edit or change the pages. Two or more learners can work on a project or activity to learn and build consensus, while writing a document together. A wiki assignment can even be written and re-written multiple times by anyone at any time. Finally, Wikis could be used to change the traditional culture of individualism in instruction to a culture where learners work together to share their construction of knowledge.

Research methodology
It was decided to use a multi-method mode of inquiry, which involved collecting both quantitative and qualitative data in an interactive case study research design. The use of such multi-method strategies could produce diverse insights regarding topics of interest and augment results’ credibility (McMillan & Schumacher, 2001). These strategies also allow for data triangulation across inquiry techniques and provide the mechanisms for mutual support.
between qualitative and quantitative research - enabling a researcher to verify the degree to which assumptions based on qualitative information are reinforced by quantitative perspectives, or vice versa (Maree & van der Westhuizen, 2007). These authors also indicated such triangulation as being critical for the facilitation of interpretive validity. We therefore ensured reliability by triangulating data and paying attention to establishing and increasing data trustworthiness.

In agreement with McMillan and Schumacher (2001), the second author had the qualitative data analysed independently by another more experienced researcher (the first author), who had not been involved in obtaining it - this provided another method for enhancing validity. Then, once agreement had been reached on the descriptive data collected, we could compare and integrate results to obtain a full representation of how educators make use of VLE tools relevant for their ODL learners across Africa.

We used a variety of strategies to enhance validity, since our research design combined quantitative and qualitative data, including the extent to which interpretations and perceptions had shared meaning between participants and researchers (Maree & van der Westhuizen, 2007). As suggested by the latter authors, we therefore decided how we ensured that data collected was valid, for example by obtaining advice from expert researchers on the questions used to ensure internal validity in terms of causal inferences, and by obtaining detailed descriptions of participants and their contexts for the facilitation of external validation and generalizability. McMillan and Schumacher (2001) agree that validity, especially in quantitative research, includes issues of reliability.

In terms of quantitative data, statistics on how many times different tools in myUnisa had been used by educators from the School of Computing during the 2011 academic year were extracted from the background system. The School of Computing has around 70 educators, with ranks ranging from Junior Lecturer through to full Professors, who formed the population for this study. The quantitative data described in the previous paragraph also provided details on who had used different tools how often. Based on these figures, educators in the School of Computing, who had used specific tools frequently, were approached for their inputs – this resulted in a so-called ‘expert’ sample of eleven educators, which was also a more manageable number in terms of obtaining the qualitative data required.

Educators were asked to shape their responses around the following issues:

Whether they felt that their active participation on myUnisa had them see any difference in their learners’ performance and/or did their learners’ pass rates improve?

They were also queried about the possible value they got from using one or more particular tool(s) - Did it make any difference / was it beneficial in their teaching of their modules?

Finally, they were requested to share their reflections on what they thought of the whole process around their use of the various myUnisa tools to teach / deliver their modules.

**Discussion of the results**

myUnisa has several different tools that educators can use, some of which were described earlier in this paper. Only the twelve tools, which were most actively used by School of Computing educators during the 2011 academic year, are represented in Table 1.
Table 1. Number of times different myUnisa tools were used.

<table>
<thead>
<tr>
<th>myUnisa tool</th>
<th>Number of times it was used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional resources</td>
<td>15 247</td>
</tr>
<tr>
<td>Blog</td>
<td>10 986</td>
</tr>
<tr>
<td>Discussion forums</td>
<td>4 297</td>
</tr>
<tr>
<td>Learning units</td>
<td>2 538</td>
</tr>
<tr>
<td>Announcements</td>
<td>2 131</td>
</tr>
<tr>
<td>Site</td>
<td>1 333</td>
</tr>
<tr>
<td>FAQs</td>
<td>1 165</td>
</tr>
<tr>
<td>Calendar</td>
<td>720</td>
</tr>
<tr>
<td>Poll</td>
<td>282</td>
</tr>
<tr>
<td>Self-assessment</td>
<td>167</td>
</tr>
<tr>
<td>Wiki</td>
<td>116</td>
</tr>
<tr>
<td>Podcast</td>
<td>12</td>
</tr>
</tbody>
</table>

Feedback from educators
The following educators’ answers were stated in fairly general terms and did not necessarily specify which tool(s) they were referring to:
Although Educator A indicated that she was going to use new tools during 2012, she did not indicate which these would be.
Educator C was of the opinion that the use of myUnisa tools might have a positive impact on especially first year learners.
Educator H saw no measureable effect on her learners’ pass rates or performance. However, in terms of her reflections on using these tools, she indicated that she received positive emails from learners appreciating the encouragement along the way!
Educator J did see a difference in her learners’ performance, with improved pass rates. The tools also made a difference in her teaching of the module: With the tools, the learners did not just get information/teaching from her, but from all the other learners as well - the tools assisted them in teaching each other, with her supervision. Her reflection was that these were very helpful tools to use.

Additional resources
Educators’ activities when using the Additional Resources tool included adding new content, revising existing content, deleting content or reading content.
During an interview with Educator K, she mentioned that although the statistics show totals for ‘content’, these numbers actually refer to actions related to Additional Resources. These accommodate learners who like to systematically evaluate resources and select the evidence that support their views (Barnes et al., 2007).
Educator E explained that learners responded well when e.g. extra help for the module, in the form of additional resources, was announced. Educator C (only half-jokingly) indicated that she doesn’t use this tool that much for teaching, but rather “as a platform to dump materials on”.

Blog
The Blog tool was used by only one academic, Educator K. She is involved in research on the use of blogs in teaching and learning. When asked whether there was a significant improvement in her learner’s marks after using this tool, she said that although her first year learners performed very well on their Assignment 3 (that involves them in blogging), they generally performed badly in the examinations: Some had 99% for Assignment 3, but only 22% for the examinations.
Her summative assessment for the module consists of a portfolio and a written examination. One explanation might be that these learners are good at reflecting, but that the stress related to the examination negates this. Another alternative might be that the workload for summative assessment is too much? She has not found any correlation between the use of blogs and learners performing well in the examinations. Her conclusion was that there are other factors that play a role in how a learner performs: Along the lines of Cant and Bothma (2010), she indicated that there are always some learners who complain that they don’t have the study materials, or have received these late from dispatch. Or there was a problem getting their prescribed textbook, or they are allowed to register late by management … All these factors or outside influences can play a role in how a learner performs, and in most cases, educators have little or no control over many of these.

Discussion forums
Educator D’s comments on this particular tool indicated that it assisted him a lot in his teaching of the module: He really “enjoyed using the discussion forum and it made a wonderful improvement on my students. In fact, it made my work easier”. Although Educator B only started teaching his modules in April of 2011, he was already using the discussion groups and announcements. The pass rate was really bad, but he agrees with Educator K that this was due to other factors apart from myUnisa.

Announcements
Educator E indicated that there was no significant difference in the pass rate of her module. However, she did feel that more learners interacted via myUnisa because of this tool, as they received emails informing them of all new announcements posted. She also saw that learners definitely reacted when announcements were about e.g. discussion classes.

FAQs
In the teaching of their modules, most educators used this tool to answer mainly non-academic questions from learners. As an specific example, Educator G used the tool to reduce the potential number of repetitive learner queries, such as how to submit assignments after the due date, or what the name of the textbook is. He also used it to avoid specific queries regarding the two editions (new and the previous edition) of the textbook that learners could use this year. Although he did not think it would affect the pass rate significantly, it does make teaching the module more manageable. He will continue to use the FAQ tool. Upon being queried, Educator F indicated that she “did not use the FAQ tool.”

Calendar
Almost half of the times that educators in the School of Computing used the Calendar tool (342; 48%) was for adding new calendar events, and 378 (52%) for revising the calendar. Educator I did not see any evidence of her learners’ pass rates improving after using this tool. However, in terms of the difference it made to her teaching of the module, she could say that it lessened queries. It helps to put all the date information in the first tutorial letter on the Calendar, as this gives a good overview for you as an educator, as well as for the learners!

Drop Box
There were no quantitative statistics available on the use of the Drop Box tool. However, despite using the drop box for submissions with feedback for the third year IT learners Educator C was teaching, it had no impact on the marks from one semester to another. In summary, it might be argued that only a few of the tools mentioned above are in fact actually used in teaching and learning. However, all of them are used to support learners in their learning.
Further research
As was the case for Ssekakubo et al. (2011), we believe that the results reported on in this paper could provide recommendations towards further research into improved deployment of LMS in developing countries. We are of the opinion that further research should be conducted to better understand the views of educators as to which learning technologies they felt would be most suitable for facilitating instruction amongst learners in the School of Computing (Cant & Bothma, 2010). It is also recommended that additional time and effort be invested towards promoting the use of VLE tools by educators.

During the interview with Educator K, she mentioned that research could be done on whether and how adding additional content and/or resources affected learners’ learning in a module, for example, by improving pass rates. Module performance (in terms of pass rates) could also be compared with educators’ activities on myUnisa. In the research reported on in this paper, educators’ references to module performance took an almost anecdotal form. This could be done in a much more quantitative way, including correlation analysis.

It could be argued that it does not matter what brilliant job an educator is doing with the myUnisa tools, if the learner does not have prior experience or the necessary skills. An investigation could therefore be launched into whether (especially first year) learners have the necessary skills to interact with the myUnisa tools provided - the obvious question in that case would be what skills they would need to use or learn with these tools. Options related to obtaining the views of learners who performed well on Assignment 3 (on blogs) and then did badly in the examinations was also discussed. Data could thus be gathered on the factors that influenced learners’ performance negatively: What changed for them … ?

Conclusions
Educators unanimously responded that they did not feel that their participation on myUnisa had them see any difference in their learners’ performance, with no pass rates improving. However, they were able to point out the value that both they and the learners got from their use of these tools, so that, in the end, these did make a difference and were beneficial in their teaching of their modules. Along with Du Plessis et al. (2011), we believe that our results make an original contribution towards scholarly debate in the field, by coordinating platforms for relationships between the various role players involved in these issues.

In their article, Heydenrych and Louw (2006) mentioned that implementing such technologies is often unsuccessful because educators lack understanding of the processes involved and the functions these technologies could fulfil in an ODL context. However, educators in the School of Computing do not seem to exhibit such a lack of understanding of how their use of the VLE tools available via myUnisa can make their teaching relevant for ODL learners across Africa. Despite possibilities related to an inappropriate approach in terms of these technologies being ‘pushed’ on them, they appear to have taken a second look at pedagogy and the nature of delivery in this context.

Despite strides already made in this regard, educators need to move further towards developing pedagogies that adapt conventional tuition in order to maximise the advantages of technology to engage these Net Generation learners (Barnes et al., 2007). However, this does not mean that they have to relinquish their positions as authorities who direct their learners’ experiences. As was the case for Cant and Bothma (2010), educators’ use of the tools available via myUnisa in reality might not be optimal. However, we believe that the positive
attitudes of most of the educators, as expressed in this research, towards using VLE tools to make their teaching relevant for ODL learners across Africa paint an encouraging picture.

References
Comparative effects of two and three dimensional methods of graphics in AutoCAD on interest of national diploma students in engineering graphics

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Abstract
This study was designed to determine comparative effects of two and three dimensional methods of graphics in AutoCAD on National Diploma students’ interest in engineering graphics. The study was a pretest, posttest, non-equivalent control group quasi-experiment which involved groups of students in their intact classes assigned to treatment groups. Two research questions and three hypotheses, tested at 0.05 level of significance, guided the study. The sample size was 227 ND I mechanical engineering technology students in the polytechnics in the south-west geo-political zone of Nigeria from which 108 students constituted treatment groups assigned to AutoCAD 2D method, and 119 students constituted another treatment groups assigned to AutoCAD 3D method. The instruments used for data collection was Engineering Graphics Interest Inventory. Mean and ANCOVA were used to analyzed the data collected. The study found AutoCAD 3D method more effective in improving students’ interest in engineering graphics than AutoCAD 2D method but the effect was not found to be significant. There was no significant effect of Gender on students’ interest in engineering graphics favouring. The study found no significant interaction effects of AutoCAD methods and gender on interest of National Diploma students in engineering graphics. Hence, irrespective of nature of gender, learners will record improved interest in engineering graphics when AutoCAD 3D method is employed for teaching.

Keywords: AutoCAD techniques, National Diploma Students, Engineering Graphics, Computer-Aided Design (CAD)

Introduction
Engineering graphics is one of the core courses for National Diploma students studying Mechanical Engineering Technology in the Nigeria Polytechnics. Engineering graphics involves construction of different geometric figures and shapes, orthographic projections, orientation of objects in space, developments of objects and intersections of regular solids and planes (National Board for Technical Education (NBTE), 2003). These contents of engineering graphics facilitate the development of skills related to technical graphics, design/drafting concepts, creativity, and spatially related problem-solving abilities in the students.

Over the years, demonstration with drawing instrument on the chalkboard is predominantly used by lecturers to teach engineering graphics to National Diploma students in the polytechnics. Demonstration is a planned performance by a vocational/technical teacher on an occupational skill/information aimed at explaining the steps/facts of an operation (Ogwo and Oranu, 2006). The method is executed by example and activities by the teacher while the students observe and listen (Ukoha and Eneogwe, 1996). Apart from the fact that demonstration method is teacher-centred, it does not provide students with learning environment that facilitates better understanding of spatial properties and relationship of objects and space (Mackenzie and Jansen, 2005; Scribner and Anderson, 2005). Spatial
visualization is an established element of engineering graphics and is integral for success in graphics and engineering as a whole (Strong and Smith, 2002). Recent attention to spatial ability in engineering graphics, according to Basham (2007), is largely due to the vast changes in computer technology and Computer-Aided Design (CAD) software packages. Well-known among the CAD packages available for graphics design in Nigeria is AutoCAD. The need to improving mechanical engineering technology students’ interaction with learning environment for better achievement and as well developing spatial ability have necessitated NBTE to include courses on CAD into the mechanical engineering technology curriculum and introduced AutoCAD to be used for teaching engineering graphics in Nigeria Polytechnics.

AutoCAD is an interactive drafting software package developed in the early 1980s by Autodesk incorporation for construction of objects on a graphics display screen According to Lemut, Pedemonte and Robotti (2000), construction of objects in AutoCAD promotes a deep understanding of the meaning of geometric construction in that, during construction process, students have to think about the definitions, properties of the geometric figures and geometric relationships. Construction strategies in AutoCAD are not free as in the pen-and-paper environment but are guided by the system’s request appearing on the command prompt. AutoCAD command prompt provides human and computer interface that enhances students’ interaction with the learning environment. Planned students’ interactions with learning environment are the most critical components of any learning environment, particularly, computer-based learning and are known to have a positive effect on students’ learning, engage students in the learning tasks, thereby helping to sustain students’ interest and help improve students’ achievement.

Interest is a persisting tendency to pay attention and enjoy some activities. Interest has been viewed as emotionally oriented behavioural trait which determines a student’s vim and vigour in tackling educational programmes or other activities (Chukwu, 2002). Besides the use of good teaching method in the classroom, another important role of the teacher is to order and structure the learning environment. Included in this role are all the decisions and actions required of the teacher to maintain order in the classroom such as laying down rules and procedures for learning and use of motivational techniques to secure and sustain the attention and interest of the learner (Moore, 1998). Students’ interest and achievement in any learning activity is sustained by the active involvement of the learners in all aspect of the learning process and interaction of the learners with the learning environment. Ogwo and Oranu (2006) and Ngwoke (2004) emphasized that unless the teacher stimulates students’ interest in learning, students’ achievement will be minimal. Hence, it is essential that lecturers teaching engineering graphics use teaching method which ensures students’ active involvement in learning and provide suitable learning environment to improve achievement and stimulate interest of National Diploma (ND) students in mechanical engineering technology to learn engineering graphics.

One aspect of AutoCAD and as in many other CAD software is that geometric construction relies on the understanding of the Cartesian Systems (2D and 3D) and the ability to relate it to objects in space. The 2D and 3D Cartesian coordinate systems, commonly used in mathematics and graphics, locate the positions of geometric forms in 2D and 3D space respectively. This system was first introduced in 1637 by a French Mathematician, Rene Descartes. The coordinate geometry based on these systems theorize that for every point in space, a set of real numbers can be assigned, and for each set of real numbers, there is a
unique point in space (Bertoline and Wiebe, 2005). The 2D coordinate system locates the positions of geometric forms in 2D space using absolute coordinate (x,y), relative coordinate (@x,y) and polar coordinate (@distance, angle). The 3D coordinate system locates the positions of geometric forms in 3D space using absolute coordinate (x,y,z), relative coordinate (@x,y,z), spherical coordinate (@ distance < angle < angle) and cylindrical coordinate (@distance < angle, distance). These two-dimensional (2D) and the three-dimensional (3D) Cartesian coordinate systems are the methods of graphics for locating the positions of geometric forms in AutoCAD 2D and 3D space respectively. Specifically, the two-dimensional (2D) method in AutoCAD involves the use of two-dimensional Cartesian coordinates system for graphics construction in AutoCAD whereas, three-dimensional (3D) method in AutoCAD involves the use of three-dimensional Cartesian coordinates system for graphics construction (Bertoline and Wiebe, 2005; Finkelstein, 2002). With these two methods of graphics in AutoCAD, users of AutoCAD have option of using any of the two methods for graphics construction to achieve the same tasks.

With the adoption of AutoCAD for teaching engineering graphics, many polytechnics have AutoCAD laboratory, and engineering graphics lecturers in the Polytechnics in Nigeria have been trained in the use of the 2D and 3D methods of graphics in AutoCAD as part of Information and Communication Technology (ICT) initiatives for academic staffs’ development. It is deemed necessary that engineering graphics lecturers in all the Polytechnics in Nigeria adopt methods of graphics in AutoCAD for teaching their students. However, in Nigeria, there is dearth of empirical data on the effectiveness of AutoCAD (2D and 3D) methods of graphics on students’ interest in engineering graphics which could serve as a directive to engineering graphics lecturers and other educators. The differences in the use of 2D and 3D methods in AutoCAD may have different effects on students’ (male and female) interest in learning engineering graphics. According to Gall, Gall and Borg (2008) education might be greatly improved if more efforts were made to match instructional methods and programs with the students who are best able to learn from them. Hence, what are the comparative effects of two and three dimensional methods of graphics in AutoCAD on interest of National Diploma students in engineering graphics?

Research questions
1. What is the effect of AutoCAD (2D, and 3D) methods on students’ interest in studying engineering graphics?
2. Is there effect of gender on the interest of students (male and female) taught engineering graphics with AutoCAD method?

Research hypotheses
The following null hypotheses tested at .05 level of significance guided this study:
传感器1： There is no significant difference between the main effect of treatments (AutoCAD 2D and 3D) methods of graphics on students’ interest in engineering graphics
传感器2： There is no significant difference between the main effect of gender (male and female) on students’ interest in engineering graphics
传感器3： There is no significant interaction effect of treatments given to students taught with AutoCAD methods of graphics and their gender with respect to their mean scores on Engineering Graphics Interest Inventory

Literature review
In any school setting, student’s motivation for learning is generally regarded as one of the most critical determinants, if not the premier determinant, of the success and quality of any learning outcome (Mitchell, 1992). High motivation and engagement in learning have consistently been linked to increased levels of student success (Kushman, Sieber, and Harold, 2000). Development of academic intrinsic motivation in students is therefore an important goal for teachers because of its inherent importance for future motivation, as well as for students effective school functioning. Motivation is the attribute that “moves” us to do or not do something. According to Harter (1981) a student has an intrinsic orientation when classroom learning is determined by internal interests such as mastery, curiosity, and preference for challenge. Students who are more intrinsically than extrinsically motivated fare better and students who are not motivated to engage in learning are unlikely to succeed (Gottfried, 1990). Higher academic standards make it more important to motivate the disengaged and discouraged students (Brewster and Fager, 2000). Successful classroom teachers are able to organize their classes and adjust their teaching strategies in a way that motivates, engages, and challenges students to learn (Demmert, 2001). Students’ interest and achievement in any learning activity is therefore, sustained by the active involvement of the students in all aspect of the learning activities.

It has been established that the student’s own feeling toward the subject matter will largely determine how much of the material will be learned and how thoroughly it will be learned. According to Ogwo and Oranu (2006) to facilitate learning, the teacher must secure and sustain the attention and interest of the students. They emphasized that unless attention is maintained and interest sustained, learning can hardly be accomplished. A state of sustained interest is shown by continued and determined readiness to learn on the part of the students as evidenced by a state of readiness to learn. Cognitive Interaction learning theories is a means of understanding the learning process for improving students’ interest with AutoCAD methods. The interactive exchange of action and feedback from the AutoCAD provides a constant learning environment.

The cognitive interaction learning theories assert that learning occurs when cognitive function interacts with the meaningful psychological environment around it. There are two forms of cognitive interaction theories namely: linear and field (Bandura, 1993).The linear and field forms of the cognitive interaction theory are very similar in nature. The linear form of cognitive interaction beliefs that perception and behavioural changes (learning) occur in sequence; while the field version of cognitive interaction states that there is a simultaneous interaction occurring between the learner and their psychological environment (Bigge and Shermis, 1998). The theory indicates that the student actually learns by doing and adapting to new conditions and perceptions. The same conditions would apply to the students using AutoCAD (2D and 3D) methods, animation and solid model in a virtual environment provided with AutoCAD. Learning by doing provides the interaction that is present in the interaction learning theory. If the student is able to interact with the computer by specifying coordinate either in 2D or 3D, view animation and solid model in AutoCAD, then according to the cognitive interaction theory, by extrapolation the student should be able to improve depth perception and increases conceptual ideas through the development of mental models which in turn improve his/her achievement. The interaction between the students and AutoCAD command and the animation provide immediate information to each other.

The need to get students involved in the classroom learning activities has called for the need for teacher to use teaching methods which are students-centred to minimize rote learning and
memorization of fact in the classroom. To facilitate students-centred instruction according to United Nation Educational Scientific and Cultural Organization (2002) educational institutions need to embrace new technology and appropriate computer technology as a learning tool to transform the present isolated, teacher-centred and text bound classroom into rich, students-centred interactive knowledge environment. Interestingly, providing opportunities to interact with course material through the use of computers and information technology tends to change the course from a competitive endeavour to one that is more collaborative, student-centred, and focused on the cognitive development and construction of knowledge in the students (Brewer, 2003). Hence, one means of constructing knowledge is to create meaning by doing. Creating support for knowledge construction within the students is a critical component to the success of developing self-motivated, intellectually stimulated learners (Osberg, Winn, Rose, Hollander, Hoffman and Char, 1997). The obvious implication of the use of computer in the classroom therefore, is to facilitate students’ interaction with the learning environment so as to sustain students’ direct interest which increases the strength of ego-involvement of the students and which does not allow the students to be distracted by trivial extraneous events in the perceptual environment.

Research method
This study was a pretest, posttest, non-equivalent control group quasi-experiment which involved groups of students in their intact classes assigned to treatment groups. The study was conducted in NBTE accredited polytechnics offering mechanical engineering technology in South-West Nigeria. The sample size was 227 ND I mechanical engineering technology students. Non-proportionate stratified random sampling technique was used to select two Federal and two State polytechnics. Each of the Federal and State Polytechnics was randomly assigned to the treatment conditions. 108 students (98 male and 10 female) constituted the treatment group assigned to AutoCAD 2D Method, while 119 students (108 male and 11 female) constituted the treatment group assigned to AutoCAD 3D method. The instruments used for data collection was Engineering Graphics Interest Inventory developed by the researcher (Appendix A). The Engineering Graphics Interest Inventory was subjected to face validation by five experts. In addition, the Engineering Graphics Interest Inventory was also subjected to construct validation. In the process of construct validation, the interest inventory was administered on equivalent sample of ND1 Mechanical engineering technology students in north-central zone of Nigeria. Factor analysis technique was used to select items that attain the factor-loading standard of 0.35. Items that failed to attain the factor loading standard or loaded on more than one factor were dropped. This is because such items are said to be factorially impure (Abonyi, 2005). Out of 40 items, a total of 28 items were finally selected. Cronbach Alpha was used to determine the internal consistency of the Engineering Graphics Interest Inventory items. The reliability coefficient computed for the Interest inventory was found to be 0.91. The data collected with Engineering Graphics Interest Inventory were analyzed using Mean, to answer the research questions while ANCOVA was used to test the three hypotheses formulated to guide this study at 0.05 level of significance.

Control of extraneous variables
To reduce experimental bias, the regular engineering graphics lecturers in the participating polytechnics taught their own students. Hence, the researcher was not directly involved in administration of the research instruments and the treatments. To control invalidity that could be caused by teacher variability in the development of the teaching guide (lesson plans) and to ensure uniform standard in the conduct of the research, the researcher personally prepared the teaching guide (the lesson plans) and organized training for participating lecturers. Two
types of Lesson plan were developed by the researcher, namely: AutoCAD 2D lesson plan and AutoCAD 3D lesson plan. The AutoCAD 2D lesson plan incorporated use of AutoCAD 2D method of graphics while AutoCAD 3D lesson plan incorporated use of AutoCAD 3D method.

**Experimental procedure**

The experiment commenced with the administration of pretest to all the treatment groups. Lecturers administered the Engineering Graphics Interest Inventory to the treatment groups in their respective schools. The pretest was followed by the treatment. AutoCAD 2009 was used for the treatment. The treatment group assigned to AutoCAD 2D method was taught with AutoCAD 2D method. The lecturers in the participating schools used the AutoCAD 2D lesson plans as a teaching guide. The use of AutoCAD 2D method emphasized students’ active involvement in the classroom activities. Active involvement was achieved through students’ interaction with AutoCAD command. The lecturers placed learning in the hands of the students by making the students specify dimensions in AutoCAD using absolute coordinate (x,y) e.g., (1,3), relative coordinate @(x,y) e.g. @(2,5) polar coordinate @(distance<angle) e.g @ (50<90), repeatedly to construct objects such as a rectangle, isometric block, ellipse, Archimedean spiral, cycloid, parabola. (Figure, 1, 2, 3, and 4). In addition, the students constructed front view of isometric object in a tiled viewport using AutoCAD 2D method to specify dimensions and converted the front view to the isometric object, by responding to extrude command, repeatedly, (Figure 5), converted the object to virtual object and view the object as a virtual object. Further, the students constructed orthographic projection, section views and auxiliary views of isometric objects with soldraw and solview commands under the lecturer’s guidance. The treatment group assigned to AutoCAD 2D method was taught 14 lessons. Each lesson lasted for 2 hours and the treatment lasted for 7 weeks.

![Figure 1: Rectangle constructed with AutoCAD 2D method](image-url)
Figure 2: Ellipse constructed with AutoCAD 2D method

Figure 3: Parabola constructed with AutoCAD 2D method

Figure 4: Isometric block with hole constructed with AutoCAD 2D method
The treatment group assigned to AutoCAD 3D method was taught with AutoCAD 3D method. Lecturers in the participating schools used the AutoCAD 3D lesson plans as a teaching guide. Students’ active involvement in the learning activities was achieved through students’ interaction with AutoCAD command. The lecturers placed learning in the hands of the students by making the students specify dimensions using absolute coordinate in three-dimension (x,y,z) e.g., (1,3,4), relative coordinate @(x,y,z) e.g. @(2,5,6) Spherical Coordinate system @(distance<angle,<angle) e.g @50<60<30, repeatedly to construct rectangle, ellipse, Archimedean spiral, cycloid, parabola. In addition, the students made use of absolute, relative and spherical coordinate to construct isometric block (See Figure 6, 7, 8 and 9).

Also, the students constructed orthographic projection, section views and Auxiliary views of isometric objects by responding to soldraw and solview commands. Furthermore, the students constructed front view of an isometric object in a tiled viewport using AutoCAD 3D method to specify dimensions and converted the front view to the isometric object, by responding to extrude command, (Figure 11), rendered the object and view the object as a virtual object. After which the students interacted repeatedly with the virtual objects in three-dimensional space through use of animation of 3D orbit, 3D continuous orbit and rotation of view point to the objects. The interactions with the use of 3D orbit, and 3D continuous orbit involved panning, twisting, rotating, and rolling of the virtual objects providing multi-point viewing relative to x,y,z coordinate system while interactions with the use view point rotation involved changing viewers’ angle to object in 3D space without changing the object’s coordinate system. For instance, a rotation of 300 degree position from X-axis in XY plane and a 35 degree from XY plane is shown in Figure 10.

The students were asked to rotate View point to isometric objects, repeatedly, by responding to vpoint command. as follows: view point rotation for angle of 270 degree in XY plane from X-axis and 90 degree from XY plane to view the TOP view of the isometric objects. View point rotation for 270 degree in XY plane from X-axis and 0 degree from XY plane to view the front view of the isometric objects. View point command rotation for 0 degree in XY
plane from X-axis and 0 degree from XY plane to view the Right Side View of the isometric objects (for example see Figure 12).

Figure 6: Rectangle constructed with AutoCAD 3D method

Figure 7: Ellipse defined by absolute coordinate 0,0,0

Figure 8: Parabola constructed with AutoCAD 3D method
Figure 9: Isometric box constructed with AutoCAD 3D method

Figure 10: Rotation of View point in AutoCAD Three-dimensional space

Figure 11: Front view of Isometric block constructed with AutoCAD 3D method at upper left corner
The treatment group assigned to AutoCAD 3D method was also taught 14 lessons, each lesson lasted for 2 hours and the treatment also lasted for 7 weeks.

The post-test was administered to all the treatment groups immediately after the completion of the treatments. The lecturers administered the post-test to the treatment groups in their respective schools. In the post-test, the Engineering Graphics Interest Inventory was administered on the treatment groups. This exercise provided the interest of the students after the treatment.

Result
Research question 1
What is the effect of AutoCAD (2D, and 3D) methods of graphics on students’ interest in studying Engineering Graphics?

Table 1: Mean of Pretest and Posttest Scores of Treatment Groups taught Engineering Graphics with AutoCAD (2D and 3D) Methods of Graphics in the Engineering Graphics Interest Inventory

<table>
<thead>
<tr>
<th>AutoCAD Methods of Graphics</th>
<th>N</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Mean Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>AutoCAD 2D Method</td>
<td>108</td>
<td>87.11</td>
<td>134.14</td>
<td>47.03</td>
</tr>
<tr>
<td>AutoCAD 3D Method</td>
<td>119</td>
<td>87.58</td>
<td>135.07</td>
<td>47.49</td>
</tr>
</tbody>
</table>

The data presented in Table 1 show that the treatment group taught engineering graphics with AutoCAD 2D method had a mean score of 87.11 in the pretest and a mean score of 134.14 in the posttest making a pretest, posttest mean gain in the treatment group taught with AutoCAD 2D method to be 47.03. The treatment group taught engineering graphics with AutoCAD 3D method had a mean score of 87.58 in the pretest and a posttest mean of 135.07 with a pretest, posttest mean gain of 47.49. With these results, both AutoCAD 2D method and AutoCAD 3D method are effective in improving students’ interest in engineering graphics but the effect of AutoCAD 3D method on students’ interest in engineering graphics is higher than the effect of AutoCAD 2D method.
Research question 2
Is there effects of gender on the interest of students (male and female) taught Engineering Graphics with AutoCAD methods?

Table 2: Mean of Pretest and Posttest of Male and Female Students Taught Engineering Graphics with AutoCAD (2D and 3D) Methods of Graphics in the Engineering Graphics Interest inventory

<table>
<thead>
<tr>
<th>AutoCAD Methods</th>
<th>Gender</th>
<th>n</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Mean Gain</th>
<th>n</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Mean Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>AutoCAD 2D Method</td>
<td>Male</td>
<td>98</td>
<td>87.18</td>
<td>134.29</td>
<td>47.11</td>
<td>108</td>
<td>87.73</td>
<td>135.23</td>
<td>47.50</td>
</tr>
<tr>
<td>AutoCAD 3D method</td>
<td>Female</td>
<td>10</td>
<td>86.40</td>
<td>133.50</td>
<td>47.10</td>
<td>11</td>
<td>86.18</td>
<td>133.45</td>
<td>47.27</td>
</tr>
</tbody>
</table>

The data presented in Table 2 show that male students taught engineering graphics with AutoCAD 2D method had mean gain of 47.11. Meanwhile, female students taught engineering graphics with AutoCAD 2D method had a mean gain of 47.10. Male students taught with AutoCAD 3D method had a mean of 47.50. Female students taught engineering graphics with AutoCAD 3D method had a mean gain of 47.27. With these results male students taught engineering graphics with AutoCAD methods had higher mean scores than female students in the Engineering Graphics Interest Inventory. Thus, there is an effect of gender on the interest of students taught engineering graphics with AutoCAD methods.

Research hypotheses
HO1: There is no significant difference between the main effect of treatments (AutoCAD 2D and 3D) methods of graphics on students’ interest in Engineering Graphics
HO2: There is no significant difference between the main effect of gender (male and female) on students’ interest in Engineering Graphics
HO3: There is no significant interaction effect of treatments given to students taught with AutoCAD methods of graphics and their gender with respect to their mean scores on engineering graphics interest inventory

Table 3: Summary of Analysis of Covariance (ANCOVA) for Test of Significance of Three Effects: Main Effect of Treatments, Gender and Interaction Effect of Treatments on Engineering Graphics Interest Inventory

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig of F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariates</td>
<td>6.358</td>
<td>1</td>
<td>6.358</td>
<td>.856</td>
<td>.356</td>
</tr>
<tr>
<td>Pre-test</td>
<td>6.358</td>
<td>1</td>
<td>6.358</td>
<td>.856</td>
<td>.356</td>
</tr>
<tr>
<td>Main Effects</td>
<td>31.694</td>
<td>2</td>
<td>15.847</td>
<td>2.135</td>
<td>.121</td>
</tr>
<tr>
<td>Treatment</td>
<td>4.516</td>
<td>1</td>
<td>4.516</td>
<td>.608</td>
<td>.436</td>
</tr>
<tr>
<td>Gender</td>
<td>28.007</td>
<td>1</td>
<td>28.007</td>
<td>3.773</td>
<td>.053</td>
</tr>
<tr>
<td>2-way Interactions</td>
<td>5.300</td>
<td>1</td>
<td>5.300</td>
<td>.714</td>
<td>.399</td>
</tr>
<tr>
<td>Treatment*Gender</td>
<td>5.300</td>
<td>1</td>
<td>5.300</td>
<td>.714</td>
<td>.399</td>
</tr>
<tr>
<td>Explained</td>
<td>91.171</td>
<td>4</td>
<td>22.793</td>
<td>3.070</td>
<td>.017</td>
</tr>
<tr>
<td>Residual</td>
<td>1648.000</td>
<td>222</td>
<td>7.423</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>1739.172</td>
<td>226</td>
<td>7.695</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at sig of F< .05

The data presented in Table 3 shows F-calculated for three effects: treatment, gender and interaction of treatment and gender on students’ interest in engineering graphics. The F-
calculated value for treatment is .608 with a significance of F at .436 which is greater than .05. Hence, the null hypothesis of no significant difference between the main effect of treatments (AutoCAD 2D and 3D methods) on students’ interest in engineering graphics was upheld at .05 level of significance. Hence, the observed difference between the mean-gain in the interest of students taught engineering graphics with AutoCAD 2D and 3D methods was not statistically significant. The F-calculated for gender stood at 3.773 with a significance of F at .053 which is greater than .05. The null-hypothesis was accepted at .05 level of significance. With this result, there was no significant difference between the main effect of gender on students’ interest in engineering graphics. The interaction effect of treatment and gender has F-calculated value of .714 with significance of F of .399 which is greater than .05. This result means that there was no significant interaction effect of treatments given to students taught with AutoCAD methods of graphics and their gender with respect to their mean scores on Engineering Graphics Interest Inventory.

**Discussion**

The data presented in Table 1 provided answer to research question one. Finding revealed that both AutoCAD 2D and AutoCAD 3D methods are effective in improving students interest in engineering graphics but the effect of AutoCAD 3D method on students’ interest in engineering graphics is higher than the effect of AutoCAD 2D method. However, analysis of covariance of the treatments effects on interest presented in Table 3 showed that there was no significant difference between the main effects of treatments (AutoCAD 2D and 3D methods) on students’ interest in engineering graphics. Thus, the difference between the effects of AutoCAD 3D method and AutoCAD 2D method on students’ interest in engineering graphics was not found significant. Analysis of covariance was used to test hypothesis three, Table 3, at the calculated F-value (.714), significance of F (.399) and confidence level of .05, the interaction effect of treatment and gender was not found to be significant. Therefore, there was no significant interaction effect of treatments given to students taught with AutoCAD methods of graphics and their gender with respect to their mean scores on engineering graphics interest inventory. This implies that the effectiveness of AutoCAD methods on students’ interest in engineering graphics does not depend on levels of gender.

Furthermore, another salient finding from this study is that male students taught engineering graphics with AutoCAD methods had higher mean scores than female students in the Engineering Graphics Interest Inventory, revealing that there is an effect attributable to gender on the interest of students taught engineering graphics with AutoCAD methods. However, analysis of covariance of test of significant difference between the main effects of gender on students’ interest in engineering graphics as presented in Table 3 showed that there was no significant difference between the main effects of gender on students’ interest in engineering graphics. This means that the observed difference in the mean interest scores of male and female students was not statistically significant. Interestingly, providing opportunities to interact with course material through the use of computers and information technology tends to change the course from a competitive endeavour to one that is more student-centred, and focused on the cognitive development and construction of knowledge in the students (Brewer, 2003). Hence, one means of constructing knowledge is to create meaning by doing. Creating support for knowledge construction within the students is a critical component to the success of developing self-motivated, intellectually stimulated learners (Osberg, et al., 1997).

**Conclusions and recommendations**
Given the technological advancement which has occasioned ample use of Computer Aided-Design packages such as AutoCAD for graphics design in the industry, the need to find the best method of CAD that will sustain students’ interest to learn engineering graphics is paramount. This study found out that AutoCAD 3D method is more effective in improving students’ interest in engineering graphics than AutoCAD 2-D technique but the effect was not found to be significant. Also, the study revealed that, although, mean interest score of male students taught with AutoCAD methods of graphics was higher than the score of female students, however, there was no significant effect of gender on students’ interest in engineering graphics. The study found out no significant interaction effects of AutoCAD methods and gender on interest of National Diploma students in engineering graphics. This simply means that the effectiveness of AutoCAD methods on students’ interest in engineering graphics does not depend on the levels of gender. Hence, irrespective of nature of gender, learners will record improved performance in their interest in engineering graphics when AutoCAD 3D method of graphics is employed for teaching.

References
Kushman, J. W., Sieber, C., & Harold, K. P. (2000). This isn’t the place for me: School dropout. In D. Capuzzi & D. R. Gross (Eds.), *Youth at risk: A prevention resource for
counselors, teachers, and parents (3rd Ed.). Alexandria, VA: American Counseling Association


271
APPENDIX A

ENGINEERING GRAPHICS INTEREST INVENTORY

Registration Number ..............................................................................

Sex: Male Female

Instruction: Below is a list of statements to ascertain your disposition towards engineering graphics. Please, check (√) to indicate the degree to which you agree or disagree with the statements.

Note: Strongly Agree (SA); Agree (A); Undecided (UD); Disagree (D); Strongly Disagree (SD)

<table>
<thead>
<tr>
<th>S/N</th>
<th>Items</th>
<th>SA</th>
<th>A</th>
<th>UD</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I like being taught graphics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>I like to be involved in design activities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>I always think about how objects like machine is constructed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>I do not like reading books that contain illustration made with diagrams</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>I like to picture the way things look in my head</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>I do not like studying in the technical drawing room</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>7</td>
<td>I found construction of objects very fascinating</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>8</td>
<td>I like fiddling with drawing instruments</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>9</td>
<td>I always encourage others to attend classes involving construction of objects</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>10</td>
<td>I do not like taking part in discussion based on properties of points and lines</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>I believe that there is prospects in being a graphics designer</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>12</td>
<td>I like to visualize objects from different perspectives</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>I don’t like learning the properties of solid objects that has height, length and width</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>I do not like answering questions in classes involving construction of solid objects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>I do not like solving problems involving conversion of solid objects that has height, length and width to plane figures that has only length and width</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>I do not like staying with graphics designers whenever they are drawing objects</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>17</td>
<td>If I were an engineering graphics teacher, I will not like to teach a class involving the development of regular solids and planes</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>I do not like to involve myself in construction activities</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>19</td>
<td>Whenever I hear the word graphics, I have a feeling of dislike</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>20</td>
<td>I compete with other students for high scores in graphics exercise and tests</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>21</td>
<td>I don’t feel at ease in a graphics class</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>22</td>
<td>Construction of objects such as machines is a waste of time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>I am always late to drawing classes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>I used to be afraid whenever I am called upon to answer questions during construction of objects that has height, length and width</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>I am exited whenever teacher is teaching construction of objects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Discussion of properties of lines, points and planes on the projection planes is very interesting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>I understand how machines work when illustrations are made with graphics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>I am exited whenever I solve problems involving construction of machines correctly</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Teachers’ views on the integration of science and indigenous knowledge systems in the South African school curriculum: The debate continues.

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Abstract

Teachers have difficulty in implementing the South African Department of Education’s IKS policy directive that an integrated science and indigenous knowledge systems curriculum should be part of the school science curriculum. This study draws on views and experiences from nineteen available teachers who were actively involved in a series of seminars and workshops presented by the Science Indigenous Knowledge Systems Project from 2008 to 2012. A Dialogical Argumentation Instructional Model based on Toulmin’s Argumentation Pattern was used in the seminars and workshops as a framework to initiate debate on socio-cultural issues. Participating teachers responded to a reflective diary questionnaire and focus group interviews and their responses were collated and clustered to serve as qualitative data for this study. Contiguity Argumentation Theory (CAT) was used to analyze the teachers’ responses, and CAT categories were applied to describe the cognitive changes that the teachers experienced. The findings suggest that the seminar-workshop series contributed to teachers making a mind shift away from their initial misgivings about the notion of integrating science and indigenous knowledge to one of acknowledging the potential benefits of an integrated science and indigenous knowledge curriculum.

Introduction

In South Africa the curricula of the General Education and Training (GET) and Further Education and Training (FET) bands have undergone progressive shifts in policy from Curriculum 2005 (C2005) of 1997 incorporating the Revised National Curriculum Statement (RNCS) of 2002 to Revised National Curriculum Statement (RNCS) of 2004 and now the current Curriculum and Assessment Policy Statements (CAPS) of 2011. All these policy documents promoted the integration of science and Indigenous Knowledge Systems in the school curriculum. Aldous and Rogan (2009) observed that teachers had difficulty in reaching the goals set by South African Science curriculum where learners are required to demonstrate an understanding of the relationship of science and technology, science and society, science and the environment and science and indigenous knowledge systems.

The Science Indigenous Knowledge Systems Project (SKISP) was initiated in the School of Science and Mathematics Education, within the Faculty of Education at a South African University in response to the National Curriculum Policy mandate “to teach Indigenous Knowledge Systems (IKS) alongside canonical school science” (Ogunniyi 2008). The debate concerning the integration of indigenous knowledge in the school curriculum was investigated and addressed in postgraduate science courses. Regular lectures, seminars and workshops attended by Honours, Masters, Doctoral, and Post-Doctoral students enabled students and participants to share ideas about their research relating to the Nature of Science (NOS), Indigenous Knowledge Systems (IKS), the integrated Nature of Science and Indigenous Knowledge Systems (NOIKS) and Dialogical Argumentation (DA) pedagogy. The interactive nature of these regular meetings provided a platform for engagement with curriculum and materials development, and the testing of accessible exemplar materials that could be utilised by teachers. This study draws on views and experiences from nineteen
available teachers who were actively involved in a series of seminars and workshops presented by the Science Indigenous Knowledge Systems Project from 2008 to 2012.

**Indigenous knowledge imperatives**

In November 2004 the incumbent Minister of Science and Technology, Mosibudi Mangena, announced the launch of the Indigenous Knowledge Systems (IKS) policy for South Africa and established the National Indigenous Knowledge Office (NIKSO) to co-ordinate Governments efforts to affirm, develop, promote and protect Indigenous Knowledge Systems in South Africa. The intention of the IKS policy is to mandate the integration of indigenous knowledge to redress colonial and apartheid suppression of indigenous knowledge systems and as a move forward to promote equity and an improvement in the lives and living conditions of all South African citizens. One outcome in the adoption of this IKS policy is to promote the collaboration between stakeholders such as government departments, science councils, tertiary institutions, Non-Government Organisations (NGO) and individual knowledge holders. The Department of Education (DoE) is viewed as a key driver in promoting and developing IKS principles. The National Qualifications Framework (NQF) embraces the view that indigenous knowledge should be integrated into the curricula and relevant accreditation frameworks. The transformation of the curriculum from a content-driven one to that of an inquiry and problem-solving one provides spaces that allow the inclusion of indigenous knowledge systems in school curricula (Department of Education, 2002).

**Literature review and theoretical framework**

Aikenhead (1996), Le Grange (2004) and Onwu (2005) argue for a complimentary framework for dealing with science and indigenous knowledge in the science classroom. The interesting development of what may be termed the ‘Third Space’ results from this amalgamation of the two knowledge systems in the cognitive processes of both educators and learners (Turnbull, 1997). Ogunniyi (1995, 2002) formulated the Contiguity Argumentation Theory in the process of traversing the dialogical space within and between people. This theory underpins the study and asserts that co-existing systems of thought exist within the consciousness of an individual. George (1999) suggests that educators should be equipped through pre and in-service programmes in designing teaching and learning strategies and teaching aids that create environments conducive for learners in order to navigate between science and indigenous knowledge and to appreciate the relevance thereof to daily lived activities. It will be argued that despite the good intentions of the new curriculum policy, science teachers in the school system experience challenges in implementing the integration of science and IKS in the science classroom due in part to its’ complex nature and lack of a viable pedagogy. Further reasons advanced for these difficulties has been the lack of trained teachers to implement it and lack of teaching resource materials amongst others (Ogunniyi, 2007 a & b, Onwu & Mosimege, 2004).

The following brief introduction to the theory base of this paper is intended to contextualise the nature of the Science Indigenous Knowledge Systems Project (SIKSP) workshops and the case study to which the sample of 19 participants were exposed and which informed their views and interactions as recorded in the reflective diary transcripts. Toulmin's Argumentation Pattern (TAP) and Ogunniyi’s Contiguity Argumentation Theory (CAT) are used as theoretical constructs and tools of analysis to understand and interpret the views and perceptions of teachers on the integration of science and indigenous knowledge systems in the school curriculum using a Dialogical Argumentation Instructional Model (DAIM).
Dialogical argumentation as an instructional tool

The recommendation of child centred approaches to teaching and learning requires a pedagogy that would encourage inquiry. One such method to promote discussion in the science class is Dialogical Argumentation (DA). Argumentation as an instructional tool has been used by many researcher to enhance teachers’ and students’ understanding of the Nature of Science (Driver et al., 2000, Eduran et al., 2004; Osborne et al., 2004; Ogunniyi, 2004,2006, 2007 a & b, 2008). According to Lawson (2004, Cited by Ogunniyi 2004) effective instruction encourages an atmosphere where ideas may be raised and then contradicted by evidence and by the arguments of others. This strategy uses persuasive argumentation as propounded in the theories of Toulmin (1958).

Toulmin’s Argumentation Pattern (TAP)

Eduran (2006 p.57), explicates the framework of Toulmin’s Argumentation Pattern (1958) as follows:

Toulmin’s Argument Pattern illustrates the structure of an argument in terms of an interconnected set of logical and sequential links. An argument may start with a claim or assertion put forwards publically for general acceptance. Data are the specific facts relied on to support the claim (evidence or grounds). Warrants provide the link between the data and the claim. Backings or generalizations strengthen the warrants. Rebuttals are the extraordinary or exceptional circumstances that may undermine the force of the supporting arguments, and indicate that a given claim would not hold true. Toulmin further considers the role of qualifiers as phrases that that show the kind of degree or reliance to be placed on the conclusions.

Within a given context, for example, a discussion on socio-scientific or socio-cultural issues, participants may posit several alternative claims or counterclaims. The robustness of a discussion can be determined by the number of counterclaims and rebuttals. TAP is particularly useful for science teachers because through this method of discussion learners are actively involved and are exposed to the power of logical reasoning implicit in the nature of science.

Contiguity Argumentation Theory (CAT)

Contiguity Argumentation Theory of cognition supports the notion that ideas move in and out of various states of the mind, depending on the context of the discourse or argument. The five cognitive categories of CAT can be used as an analytical tool by researchers to explain views held by teachers on science-IKS worldviews. One of which would express most closely the participants present mental or cognitive state. The five CAT categories are defined in Table 1 (Ogunniyi, 2002).

Whereas TAP provides an understanding of the dynamics of logical argumentation, CAT allows self-evaluation of the present mental state with regard to a set of mental cognitive states brought about through thoughtful consideration of beliefs and culture. Ideas flow in and out of these cognitive states through experiential exposures of one or other form (Ogunniyi, 2004).

Table 1: Contiguity cognitive states of the Contiguity Argumentation Theory (CAT)
### Cognitive states

<table>
<thead>
<tr>
<th>Categories</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dominant</td>
<td>A powerful idea explains and predicts facts and events effectively and convincingly or resonates with an acceptable social norm that affords an individual a sense of identity e.g. a scientific explanation of lightning in terms of static electricity as opposed to the explanation proffered for the same phenomenon within an indigenous worldview.</td>
</tr>
<tr>
<td>Suppressed</td>
<td>An idea becomes suppressed in the face of more valid, predictive, empirically testable evidence, or established social norms e.g. the scientific explanation of the cause of a disease may be suppressed in the face of cultural beliefs about possible diabolical motives of enemies behind the disease.</td>
</tr>
<tr>
<td>Assimilatory</td>
<td>A less powerful idea might be assimilated into a more powerful one in terms of the persuasiveness or adaptability of the dominant idea to a given context e.g. the indigenous idea of not leaning against a metal pole, tree or wall which may have arisen from experience can easily be assimilated into the scientific concept of lightning as an electrical phenomenon</td>
</tr>
<tr>
<td>Emergent</td>
<td>There may be circumstances where no prior idea exists and a new one has to be acquired or developed e.g. a considerable amount of scientific concepts such as atoms, molecules, magnetism, conservation of matter, laws of motion, etc. have usually been learnt from school science.</td>
</tr>
<tr>
<td>Equipollent</td>
<td>When two competing ideas have comparably equal intellectual force, the ideas tend to co-exist without necessarily resulting in a conflict e.g. the theory of evolution versus creationism.</td>
</tr>
</tbody>
</table>

(Ogunniyi, 2002; Ogunniyi & Hewson, 2008)

### A Dialogical Argumentation Model

Participants involved in SKISP workshops and seminars were actively involved in developing a practical framework to assist science educators to design a dialogical argumentation model for teaching science/IKS topics in an interactive way.

The model is an attempt to provide a practical framework to assist:

- **Lecturers** in designing a dialogical argumentation programme for teaching science/IKS topics in an interactive way.
- **Science teachers** to lead learners to a greater understanding of socio-ecological, indigenous knowledge and health promotion concepts (Henton, 1996).
- **Teachers and learners** to reach optimum levels of critical thinking by applying dialogical argumentation in reaching decisions
In developing a **teaching methodology** that transcends the bounds of normal training and research, **Science education researchers** in following through an implementation process with cohorts of teachers studying science education programmes at the pre-service and in-service levels at University.

Science educators should be fully engaged in the development of teaching and learning material that recognises the interface and interconnectedness between science and Indigenous Knowledge Systems (Michie & Linkson, 1999). In order to achieve the goal of cognitive harmonisation or understanding and appreciation of viewpoints, the model suggests paying attention to the narratives of the experiences of the participants, their understandings of science-IKS concepts and the complexities of using a Dialogical Argumentation Instructional Model.

The **DAIM model** in the classroom context follows a series of stages (Refer Figure 1)

**STAGE 1: THE NODAL POINT:** The process starts with the selection of a socio-scientific topic with a debatable controversial socio-cultural dimension that includes conceptual science and indigenous ways of knowing.

**STAGE 2: INDIVIDUAL TASK:** The learners investigate a topic by engaging in a problem orientated issue, or by reading a narrative about an issue, problem, controversy, context or concern. Each individual learner is required to think about and formulate an opinion (claim) supported by reasons (evidence, data) in response to a series of questions. Learners record their claims and reasons (grounds) in writing. This step is regarded as individual dialogical argumentation or **intra-dialogical argumentation** as the thinking is like conducting a conversation with oneself. Thus thinking spaces are consciously created by the teacher facilitator.

**STAGE 3: GROUP TASK:** Individuals share their views within a small group with the intention of establishing claims and counterclaims and reaching consensus or an agreed point of view. This “sharing space” can be regarded as **inter-dialogical argumentation** as it occurs between participants in the group. The purpose is to reach a common group understanding of the issue under consideration.

**STAGE 4: GROUP PRESENTATION:** Each group in the class selects a presenter who will share that group’s point of view (claims and counterclaims, evidence and warrants) with the rest of the class. This is done through a text poster and an oral presentation but without any discussion.

**STAGE 5: WHOLE CLASS DISCOURSE:** Mediation by the facilitator (teacher) is initiated and the entire class has an opportunity to contribute further arguments based on evidence, (grounds i.e. data supported by warrants, backings or qualifiers). Particular note is taken of opposing claims or rebuttals. The whole class debate is facilitated by the teacher. This stage recognises the participants contribution to joint co-construction of knowledge understanding through the identification of trends, themes and a meta-cognitive view about the issue under consideration. The objective is to highlight disagreement and ultimately to reach a common understanding or consensus or viewpoint called cognitive harmonisation.
STAGE 6: COGNITIVE HARMONISATION: The purpose of hosting whole class discussion is to strengthen the consensus reached, and to air any nagging concerns that may exist. The process contributes to facilitating cognitive harmonization of a concept or concepts under discussion. The harmonization process begins with stage 1, the nodal point and fans out in ever widening expansions as dialogical argumentation generate fresh new insights into the epistemology of the issue under consideration. This stage can also be used in a reflexive way for teachers and learners to assess levels of understanding of the topic. Toulmin’s Argumentation Pattern (TAP) can be used to score the level at which dialogical argumentation occurs.

Figure 1. Dialogical Argumentation Instructional Model (DAIM) for teaching integrated science and indigenous knowledge systems lessons to promote an evolving cognitive harmonisation and understanding of socio-cultural-scientific issues. (Adapted from Langenhoven & Ogunniyi, 2009).
Methodology
The purpose of this study is to explore teacher’s perception about the DoE policy directives to implement an integrated science and indigenous knowledge systems curriculum in the classroom. The focus in this paper will be an analysis of the responses offered by a group of 19 teachers who attended a series of seminars and workshops from 2008 – 2012. The teachers were requested to reflect on their experiences within the SKISP project in a questionnaire entitled:

A Reflective Diary on the Science and Indigenous Knowledge Systems (SIKSP) Dialogical Argumentation Instructional Model (DAIM)

The following instruction preceded the questionnaire that consisted of five questions.

You have been involved in the SIKSP Dialogical Argumentation Instructional Model through lectures, seminars and workshops for a while now. Some of you took modules relating to integrating science and indigenous knowledge (IK) in the classroom e.g. the Socio-psyc

The paper is a case study that explores themes and trends that emerge from the responses made by the cohort of 19 teachers to Question 2 (a), specifically.

In what ways have your experiences in the SIKSP or related activities (modules, seminars and workshops) informed the way you i.e. bring coherence to, or make sense of the pieces of information or experiences) you have acquired in terms of the way you construed the controversial issue of integrating science and indigenous knowledge (IK) at the time you started participating in the activities, during the period of your involvement, and now?

The data obtained from the teachers’ responses to question 2a of the reflective diary were carefully scrutinised to identify how the teachers’ experiences informed the way they made sense of the policy directive to integrate science and indigenous knowledge systems in the school science curriculum. The teachers’ responses (views and experiences) were transcribed and clustered into three groups according to the way they construed the “controversial issue” before, during and after the seminar-workshop series. The experiences and activities identified by the teachers as being the most influential during participation were grouped into nine categories with an assigned code for each category. The tabulated data thus arrived was summarised as reflected in Table 2. This analysis generated the following research questions:
**Research questions**
What were teachers’ initial views about the integration of science and indigenous knowledge in the science classroom?
Which seminar and workshop activities influenced and enabled the teachers to navigate, frame or make sense of implementing an integrated science and indigenous knowledge curriculum?
To what extent has dialogical argumentation as an instructional method influenced teachers’ views on the integration of science and indigenous knowledge?

**Results and findings**
In order to remain within the constraints of the technical aspects of this paper a selection of exemplar responses will be made. In addition the teacher’s responses will be linked to the CAT categories to identify cognitive changes with respect to the inclusion of IKS in the school science curriculum.

**Responses to research question one**

*What were teachers’ initial views about the integration of science and indigenous knowledge in the science classroom?*

The narrative of teacher’s experiences prior to their involvement with the science indigenous knowledge project workshops were clustered into three groups based on their responses:

**Group 1**: Indigenous Knowledge Systems (IKS) as an unfamiliar term.

**Group 2**: Perceptions that Indigenous Knowledge Systems (IKS), is about superstition, myth and witchcraft.

**Group 3**: Reservations about the feasibility of implementing an integrated science-IKS curriculum.

**Group 1**: Indigenous Knowledge Systems (IKS) as an unfamiliar term.

Prior to post-graduate studies and/or involvement with SIKSP teachers indicated that they were unfamiliar with the term IKS and therefore did not consider it important.

T14: The first time I participated in the SIKSP project the concept of IK and IKS were new to me. I did not even hear about them and obviously could not think about integrating science with IK in the school system.

T7: At the beginning it (IKS) was not visible in the curriculum: there was only occasional reference to it when dealing with Learning Outcome 3 (Science and Society). I did not spend much time on IKS topics simply because I did not see it as is important.

**Group 2**: Perceptions that Indigenous Knowledge Systems (IKS), is about superstition, myth and witchcraft.

A recurring perception among teachers indicates that they were of the opinion that IKS was about superstition, myth and witchcraft, and that indigenous knowledge was considered as backward among those who are educated. (Science – dominant, IKS – suppressed)
T6: There has been talk that IKS is associated with myths and witchcraft and that there was no way that IKS and science could coexist.

T9: Before the workshop... I thought that Western Science is dominant over IKS. Western (science) is the only science that can heal people. In my view IKS was all about witchcraft. I was not so fascinated by IKS at all in science education.

Group 3: Reservations about the feasibility of implementing an integrated science-IKS curriculum.

Teachers were initially uncertain about how to implement the process of integrating IKS and science in the school science curriculum, and were of the opinion that there would be opposition to the implementation of the policy mandate.

T3: At the beginning when I started, I felt that IKS and science were two different knowledge systems and that it was impossible to combine the two. In my view integration of the two would bring confusion to learners because I was of the view that IK explanations are not the same as those of school science.

T16: Before attending SKISP seminars I did not know how to integrate the two and I struggled with conveying the lessons to my learners. The curriculum expected teachers to include IK in their lessons but never offered any training or whatsoever.

T15: In my own teaching with pre-service educators, my attempts at integrating IK content according to the dictates of curriculum was more of the nature of adding anecdotal information about cultural practices that could be linked to modern science practice.

It is evident that prior to their post-graduate studies and involvement with SIKSP, teachers were unfamiliar with what the term Indigenous Knowledge Systems entailed. Many thought that indigenous knowledge was about superstition and witchcraft, consequently they expressed doubts about the integration of Western Science and IKS in the school science curriculum. This uncertainty points to hesitation in dealing with the education policy imperative to integrate science and IKS in the school curriculum.

Responses to research question two

Which activities, during their involvement were most influential, and enabled the teachers to navigate, frame or make sense of implementing an integrated science and indigenous knowledge curriculum?

The analysis of teachers responses identified nine categories of activities within the SIKSP project that influenced the way that they made sense of socio-cultural issues and the teaching or implementation of a science-IK curriculum in the classroom. These categories are ranked in descending order of occurrence. Refer to Table 2.
Table 2: A classification table of activities that were most influential in enabling the Science Indigenous Knowledge Systems Project (SIKSP) participant’s to navigate, frame and make sense of implementing an integrated science and indigenous knowledge curriculum. Ranked and coded in descending order. (N=19)

<table>
<thead>
<tr>
<th>No.</th>
<th>Coded categories of influence</th>
<th>No. of references</th>
<th>%</th>
<th>Context and pertinent observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>(APG) Active Participation and group interaction within SIKSP</td>
<td>15</td>
<td>30%</td>
<td>The role of interactive participation and sharing of ideas and experiences with peers.</td>
</tr>
<tr>
<td>2.</td>
<td>(DA) Reference to effects of dialogical argumentation</td>
<td>11</td>
<td>22%</td>
<td>Investigating strategies for promoting and sustaining dialogical argumentation. Dialogical argumentation as a strategy for promoting the inclusion of IKS.</td>
</tr>
<tr>
<td>3.</td>
<td>(W) Workshops</td>
<td>6</td>
<td>12%</td>
<td>Attending workshops influenced and changed perceptions regarding NOS and NIKS.</td>
</tr>
<tr>
<td>4.</td>
<td>(CMD) Classroom Materials Development</td>
<td>4</td>
<td>8%</td>
<td>Classroom material development provided a platform for engagement and a nodal point from which socio-scientific discourse emerged.</td>
</tr>
<tr>
<td>5.</td>
<td>(PR) Personal postgraduate research</td>
<td>4</td>
<td>8%</td>
<td>Post graduate research studies in various contexts e.g. own class, school based research or teacher training.</td>
</tr>
<tr>
<td>6.</td>
<td>(S) Seminars</td>
<td>3</td>
<td>6%</td>
<td>Seminars, where ideas and activities relating to IKS were shared, had a positive effect.</td>
</tr>
<tr>
<td>7.</td>
<td>(CM) Coursework Modules</td>
<td>3</td>
<td>6%</td>
<td>Post-graduate</td>
</tr>
</tbody>
</table>
coursework modules where participants were introduced to dialogical argumentation and strategies for integrating IKS and Western science.

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</thead>
<tbody>
<tr>
<td>8. (CO)</td>
<td>Classroom observations of SIKSP activities &amp; research projects</td>
<td>2</td>
<td>4%</td>
</tr>
<tr>
<td>9. (SI)</td>
<td>Sharing Practical ideas &amp; experiences beyond SIKSP</td>
<td>2</td>
<td>4%</td>
</tr>
</tbody>
</table>

<p>| | | | |</p>
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</thead>
<tbody>
<tr>
<td>Total number of response references</td>
<td>50</td>
<td>100%</td>
<td></td>
</tr>
</tbody>
</table>

A perusal of the categories of influence listed in Table 2 indicated that 30% (15) of the responses were strongly influenced by their Active Participation and group interaction within SIKSP (APG). This implies that teachers appreciated the interactive participation and the sharing of ideas and strategies with their peers and colleagues.

T2: In the process of interacting with my peers we underwent rigorous sharing of ideas about science and IK integration.

T5: Participation in the SKISP and research in schools have made me see that it is possible to teach both science and IK-i.e. integration is possible.

T18: My experiences in the SIKSP activities have reformed my way of thinking, doing things completely different. When I started I did not appreciate indigenous knowledge nor did I realise its richness until I matured in these workshops.

The Workshops (W) (12%), Seminars (S) (6%) and Coursework Modules (CM) (6%) were an integral part of SKISP. The modus operandi of all these activities was interactive and involved testing and exchanging ideas. Reference to these categories of influence reaffirm that the primary influence of SIKSP was embedded in the camaraderie and the sharing of experiences and combined with the first category includes 54% of teachers overall responses.

T3: During coursework and having gone through workshops and seminars, I came to understand that without Nature of Science and Nature of Indigenous Knowledge Systems (NOSNIKS) and argumentation it would be almost impossible to integrate the two.

T9: After attending the workshops I realized that IKS is not something new to me, perhaps the terminology. My dad had a Zulu background, and my mum a Coloured.
Medicinal plants were the order of the day. Together they used their indigenous knowledge to heal us when we were sick by making their own medicines.

A core element of SKISP activities involved the development, testing and implementation of Dialogical Argumentation Instructional Model (DAIM) for integrating science and indigenous knowledge in the classroom. 22% of the teachers referred to the positive effects of dialogical argumentation pedagogy in their overall responses.

T11: I think for the time that I have been exposed to argumentation (DA) I have learnt to look at things differently especially the traditional way I grew up in. There is a tendency in me that when you are educated you do not look at some traditional practices. Not that I had anything against it, but I did not understand the ways since they were not explained to me.

T15: In our work with pre-service and in-service teachers in the SIKSP programme, we investigated strategies and resources for promoting and sustaining argumentation in the science classroom. Some of the pedagogical strategies that would complement these activities included co-ordination of group discussions, presentations as well as asking questions that would stimulate argumentation, such as “What is your evidence? How do you know?”

Classroom material development workshops sessions directed at exploring the content of the Curriculum Assessment Policy (CAPS) provided a platform for engagement and a nodal point from which socio-scientific discourse emerged. Four teacher responses (8%) indicated that materials development activities had a positive influence and enabled them to take cognisance of the debate around the integration of science and indigenous knowledge.

T8: The curriculum materials development provided a platform of engagement at conferences, institutions and developing new module descriptors at Higher Education Institutions for science education courses that would note NOS, IKS and Dialogical Argumentation (DA) pedagogy.

T15: The resource materials produced during SIKSP project worked were useful instructional tools. My own PhD work with pre-service teachers led to the development of training resource materials on argumentation.

These two teachers were involved in post graduate studies and referred to how personal research and practical classroom experiences influenced their attitude towards implementing integrated science and IKS lessons.

T5: Participation in the SKISP and research in schools have made me see that it is possible to teach both science and IK.

T7: When exposed to IKS in my Honour’s and Master’s training, the relevance and importance of it became clear to me. I tried to make it part of most of my lessons where possible.

One positive aspect of teacher interaction with SIKSP was the cascade effect reflected by the reference by these two teachers to their growing confidence and their abilities to support colleagues in implementing a science and IKS curriculum in the classroom.
T19: At this stage I am guiding and supporting my colleagues at my school on how to integrate and plan their lessons.

T4: I feel confident to promote the use of a Science-IK curriculum after my involvement and exposure with the SIKSP Program which opens up a world of possibilities.

Responses to research question three

To what extent has dialogical argumentation influenced teachers’ views on the integration of science and indigenous knowledge?

Teacher involvement with SKISP, their interactive experiences with peers and colleagues and personal post-graduate research, strongly influenced their current perceptions about the relevance of indigenous knowledge, the issue of integrating science and IKS in the classroom and the implementation of an argumentation instruction model.

The relevance and appreciation of teachers’ own cultural knowledge was expressed in several ways.

T3: I have further noted that IK is not just knowledge of the past, but many people are still using it nowadays, hence it is knowledge that is authentic to a particular person’s experience and by no means inferior to present day technology. In fact there are areas in which IK could possibly intervene where present day scientific innovations have failed.

T14: Now I have got basic knowledge of IK and IK practices. The exposure I got in seminars helped me to appreciate the efforts and creativity of our ancestors and their practices. Thus I will work hard to convince the curriculum officials of my country to consider the relevance of IK practices and introduce it in the school curriculum.

Teachers referred to the possibility of using cultural knowledge to explore difficult science concepts.

T4: The SIKSP program opens up a world of possibilities in acquiring the right frame of mind how to use cultural knowledge/home knowledge to explain difficult science concepts in the classroom.

T8: The approach to recognize the knowledge that learners and teachers bring to the class is a nodal point from which socio-scientific discourse can emerge.

After the engagement with SIKSP activities teachers were more amenable to implementing an integrated science and IKS curriculum in their classrooms.

T5: I think that my participation in the SIKSP and research in the schools have made me see that it is possible to teach both science and IK in an atmosphere of trust and discussion where IK is respected and not renegaded or downgraded.

T18: I have now reached a level where I am confident of integrating these two world views harmoniously. The activities have instilled in me that teaching science using IK is inevitable.
T1: Although integration might seem cumbersome and time consuming versus the more efficient modern science integration will show how modern science and applications have perhaps been based on IK conceptions.

A key component of SIKSP activities was the development of a dialogical argumentation instructional model (DAIM) as a strategy to accommodate and facilitate the integration of science and IKS.

T11: The exposure to argumentation has changed me ways I look at everything around me, dialogue etc. I am still learning the ropes but I see it as a premise for making science learning meaningful. It gives students a stronger basis for building new knowledge. I think I am becoming more critical now and I can express myself better without being offensive

T17: I have come to the conclusion that the use of dialogical argumentation is a very effective method for teaching any subject, especially science in contiguity with IK. This is because argumentation elucidates the science in the IK and the IK in the science.

**Summation of findings**

The analysis of the participant teachers’ responses, regarding their collective involvement with SKISP, revealed progressive changes in mindset of their perceptions about the integration of science and IKS. Before participation there was generally a negative attitude towards the integration of IKS in the science curriculum. Reasons that were given indicated a lack of understanding about the domain of indigenous knowledge and its possible connection to science. Acceptance of an IKS framework was suppressed, and modern science prevailed as the dominant mindset. This was concisely articulate by T3:

T3 ‘The hegemonic power of science framed my thinking and viewing of the world. I believed that as teachers we need to teach pure science and not superstitions or untested truths’.

SKISP promoted interactive participation, the communal sharing of ideas during workshops, and seminars. Dialogical argumentation using DAIM was used as a framework to scaffold discussions. Teachers were encouraged to use argumentation in their personal research agendas, and to focus their reading and research relating to IKS and NOS. The shared space initiated a change in the teachers’ attitudes towards the CAPS policy mandate. A more cohesive understanding of the domains of NOS and NOIKS was gradually assimilated and new conceptions emerged where originally little or no well-formed prior knowledge or understanding of the debate existed (Ogunniyi 208b).

The teacher’s responses after extended participation indicated that many had reached a state of equipollence i.e. a state where two competing ideas of comparably equal intellectual force viz. indigenous knowledge and modern science, could co-exist without resulting in conflict.

T5 comments, Participation in the SIKSP and research in school have made me see that it is possible to teach both science and IK.
T18 comments, I have now reached a level where I am confident of integrating these two world views harmoniously. The activities have instilled in me that teaching science using IK is inevitable.

The dialogical argumentation based instructional model (DAIM) promoted within the SKISP stands in sharp contrast to the current instructional practices evident in many South African schools viz. a focus on transmission of a host of scientific facts (Driver et al, 200) or simple regurgitation of experimental details (Niaz et al., 2002). In keeping with observations made by other researcher in the field of argumentation (Osborne, et al 2004; Abd-El-Khalick,2005; Simon, et. al, 2006), interactive argumentation and reflection were found to encourage participants to externalize their thought, clear their doubts, and reach a degree of consensus about the ongoing debate about integrating science and IKS. Responses by the teachers indicate that they regarded dialogical argumentation as an effective strategy for implementing integrated science lessons. The sentiment was pertinently expressed by T17:

T17 I have come to the conclusion that the use of dialogical argumentation is a very effective method for teaching any subject, especially science in contiguity with IK. This is because argumentation elucidates the science in the IK, and the IK in the science.

**Conclusion**
To conclude, it is pertinent to reiterate important observations that the teacher’s responses highlight. The integration of IKS into mainstream science may bring about a paradigm shift to the teaching and learning of science as can be seen by the shift in teacher’s views of their experiences before, during and after the SIKSP seminar – workshop series. IKS is embedded with valuable knowledge that can benefit human kind if properly harnessed. Infusing indigenous knowledge in the school and higher education curricula would establish information longevity and facilitate further research and development into for example medicinal plants (Lazarus, 2011) traditional food plant, animal husbandry, sustainable agricultural practices and environmental conservation. The inclusion of indigenous knowledge into the teaching and learning programmes of the school and higher education curricula can have a positive impact on poverty alleviation and redressing inequalities such as those against women, who are the holders of much of the indigenous knowledge within communities. It requires educators to develop new instructional strategies that will enable learners to acquire the ability to develop scientific understanding without losing their sense of social identity. This creates interesting challenges for lesson planning and instructional practice.

The resistance of teachers and learners to engage with IKS is an aspect of concern. A great deal of research needs to be done in order to develop curriculum resource materials and teacher guides to assist teachers to implement an integrated science and indigenous knowledge curriculum.

The challenge for the South African government and civil society is to bring about synergy in terms of indigenous and western knowledge systems so that knowledge generation and utilization benefits all segments of South African society without causing disparities or lopsided development (NIKSO 2004).

**References**


Teaching thinking, study, investigative and problem solving skills in biology: A case of curriculum implementation in Zomba schools

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Abstract
This paper reports on a study of how new content free topics in Junior Secondary Biology were perceived by teachers as a way of exploring the implemented curriculum. The topics were study, thinking, investigative and problem solving skills. It was hypothesized that there would be a mismatch between what the curriculum developers and textbook writers desired and how teachers taught them, since teachers had no experience in them. Questionnaires were administered to 32 teachers from randomly selected schools in Zomba, an administrative district in southern Malawi. The results were analysed using a theory of curriculum implementation developed by Rogan and Grayson (2003). This theory has three interrelated constructs namely Profile of Implementation Capacity to Innovate and Outside Support. The study found that there were inadequate Outside Support and Capacity to Innovate which resulted in low level Profile of Implementation. Underqualified teachers in low resourced schools said the topics were difficult, but tried to teach them as presented in the syllabus. On the other more qualified teachers in better resourced schools left out many of the objectives in their teaching, although they saw them as easy. Although teachers appreciated the value of the new topics in assisting learners in understanding and skill acquisition, they showed generally more negative perception of the new topics with remarks such as difficult, boring and irrelevant. They felt they needed in-service training on the teaching of the new topics and provision of more resource materials for them to teach more effectively.

Background and purpose of study
In the Malawi Junior Secondary Biology curriculum of 2000, in addition to regular biology topics comprising Plant biology, Human and Animal biology, Human diseases, Genetics and Evolution and Environment, new content free topics, such as Thinking, Study, Investigative and Problem Solving skills were introduced to assist learners become better learners. This study was done to find out teachers’ perception and experience in teaching these new topics, as a way of gaining insight into the implementation of these new curriculum topics.

The need to introduce study skills was highlighted by the work of Davies and Greene (1985) which showed that science learners have difficulties using science texts. Generally, science texts are difficult to read because the language is impersonal and complex in structure. There is concentration of concepts, with limited elaboration. Furthermore, unlike in literature where learners are assisted by teachers to focus on key issues, science teachers tend to offer limited assistance to learners in the use of textbooks. Davies and Greene (1985) devised a reading scheme called “Directed Activities Related to Texts (DARTS), whose aim is to help learners acquire skills of getting information from secondary sources. The new Biology syllabus included DARTS with the aim that these skills will eventually become part of learners’ repertoire of study skills.

The thinking skills introduced in the new syllabus were derived from the works of Adey and Shayer (1994), Kunje (1987), Mbano (2001, 2003a). Using Piaget’s cognitive development theory (Inhelder and Piaget, 1958), Shayer and Adey (1981) showed that much of secondary school science would require formal operational thinking, yet less than 20% of learners in
secondary school classes attain this level of thinking. In view of this problem, Adey, Shayer and Yates (1989) devised an intervention programme, called Cognitive Acceleration through Science Education (CASE), which aims to increase the proportion of formal operation thinkers in secondary classes. These lessons were successfully adapted to Malawi schools (Mbano, 2001, 2003b, Mbano, Nampota and Dzama, 2005). The thinking skills component of the syllabus enhances the formal operational thinking competence necessary for the study science.

Consistent with most science curriculums, which endeavour to foster appropriate attitudes, thoughts and approaches, investigations and problem solving in science were introduced as stand-alone topics in the syllabus. In the previous syllabus these topics were not addressed directly, it being assumed that if the content topics are taught correctly learners would contingently acquire skills for doing scientific investigations (Malawi Certificate of Education and Testing Board, 1972). However, research has shown that there is need to include this content in order for teachers to give it the required attention (Gott and Duggan, 1995). Consequently, the current Biology Syllabus describes the content of this topic fully.

When the new curriculum was being introduced orientation workshops were organised for the teachers. Furthermore, locally written textbooks have been produced such as Mhlanga, Ndolo and Mbano (1998) Strides in Biology, Medi and Meredith 1998) The new Junior Certificate Biology which have addressed these topics; this is in line with requirements for any core subject in the syllabus. An analysis of JCE examinations shows that these topics are tested; for example in 2003, 2004, 2005 and 2006 examinations these topics accounted for 21%, 8%, 21%, and 21% of the examinations’ total marks respectively. This shows that the topics have been incorporated in the Biology curriculum.

In Malawi, education is centrally managed with same structure in all districts, and learners in public schools follow a national curriculum. The public sector has two main categories of secondary schools: Conventional Secondary Schools (CSSs) and Community Day Secondary schools (CDSSs). Unlike CSSs, CDSSs started out as distance education centres and were in 1998 converted into face to face secondary schools by a government directive. However, the change in status from centres of distance education to CDSSs occurred without accompanying improvement in resources. Consequently, CDSSs are poorly resourced with inadequate classrooms, teachers, science laboratories and textbooks. Learners in these schools do not perform as well as those in conventional schools on national examinations. This study compared how teachers in CDSS and CSS perceived the new topics in Biology.

**Problem identification and research questions**

There is often a mismatch between the intended and implemented curriculum (Cuban, 1993). Since the topics of study, thinking, investigative and problem skills are new in the curriculum and teachers did not learn them as school learners, nor did they study them during their teacher education, it is likely that they lack content and pedagogical knowledge and skills to teach the topics effectively. Furthermore, since the topics do not have the normal biological content some teachers may not easily perceive their relevance. In addition, the orientation workshops for the new syllabus being brief, lasting few days and with no follow up, it is quite possible that these topics were not have been addressed adequately. It is therefore hypothesised that the teachers will have negative attitude to the topics and so may not teach them effectively. This study explored the following research questions:

- How easy or difficult do teachers perceive the teaching of the topics to be?
- Of what value do teachers attach to the topics?
- What difficulties do teachers encounter in teaching the topics?
- What support did the teachers receive in implementing the new curriculum?
How could the teaching of the topics be improved?

**Theoretical considerations**

It is common in a curriculum implementation study to consider three dimensions of the curriculum namely; intended, implemented and attained curriculum ((Martin and Kelly, 1996; Travers and Westbury, 1989). The intended curriculum can simply put be represented at subject level by the syllabus. The implemented curriculum refers to practice and activities at classroom level. The attained curriculum represents what learners have learnt (Schimdt et al, 1996). In this study the intended curriculum is represented by the description of the new topics in the syllabus, the implemented curriculum could be represented how topics are rendered in textbooks and taught in classrooms and attained curriculum what skills the learners achieve. However this conceptual framework is commonly seen as deficient model, documenting the gap without explaining how it comes about and how it can be bridged. Rogan and Grayson (2004, 2003; Rogan, 2007), however, have developed a theory, drawing on school development, education change and science education literature, for implementing curriculum change in developing countries, which has three interrelated constructs namely Implementation Profile, Capacity to Innovate and Outside Support (see Figure 1).

Implementation profile focuses on the change that is desired to take place and how it is going to happen. It takes into account existing practices and skills and maps a number of ways to reach the desired change. In the case of this study the sub components of the Implementation Profile would include active learning approaches, Thinking skills, Investigative and problem solving and Study skills. Capacity to Innovate focuses on factors in the school that can hinder or foster the change. They usually include physical resources, teacher factors, learner factors and school management. In this study this would include presence of science laboratories, teacher qualifications, and continuing professional development (CPD) in the schools. Outside Support focuses on inputs from the Ministry of Education and community. In this case this could include textbooks, teacher’s guide, orientation of teachers, and supervision of teachers.

The theory incorporates concept of Level of Use from Hall and Loucks (1977) which has four main stages namely Orientation and Preparation, Mechanical and Routine Use, Refinement and Integration, and Renewal. During Orientation and Preparation Level teachers become aware of the new curriculum and may find out more and acquire syllabus and textbook as they prepare to teach. At the level of Mechanical and Routine use teachers teach according to what the developers want without modification or adaptation to local context. During the third stage of Refinement and Integration teachers collaborate with colleagues and use the curriculum flexibly, harnessing its strengths and minimising its weakness to meet their local needs. In the final stage of Renewal teachers make major changes to the curriculum in order to make it more effective. Rogan and Grayson (2003) have given examples of the four levels for the three constructs and their subcomponents without necessarily spelling out how those levels are arrived at.
The Rogan and Grayson (2003, 2004) theory of curriculum implementation not only describes the gap between intended and implemented curriculum, but explains how the relationship between the three constructs bring about the level of implementation at each point. Furthermore, the implementation process is seen as an incremental process, building upon current practices. They have adapted Vygostky’s concept of Zone of Proximal development (ZPD) to curriculum process to develop the concept of Zone of Feasible Innovation (ZFI). ZFI refers to gap between current practice and the demands of the new curriculum. They suggest that there is need for teachers to take small incremental steps, just ahead of current practice in order to successfully implement a new curriculum. They propose that curriculum change implementation is more likely to be successful if it is school based.

In a review of curriculum studies in mathematics and science using Rogan and Grayson Curriculum Implementation Theory, Lelliot et al (2009) found that most studies focussed on the two constructs: Implementation Profile and Capacity to Innovate. There were few studies on Outside Support. However in Malawi Outside Support would be a main issue in determining the extent of implementation of a new curriculum.

**Method**
The study used a self-report questionnaire on teacher’s perceptions of teaching the new topics. This was considered relevant because the purpose of research was to find out the implemented curriculum through soliciting teachers’ views and experience of teaching the new topics. Furthermore, there was comparison between CDSS and CSS teachers.
The questionnaire had four parts. The first part elicited personal details and school characteristics from teachers. The second part listed the objectives of the new topics and requested teachers to indicate the level of difficulty. The third part required teachers to indicate level of support they had received relating to new topics. The final section was an open-ended inquiry into their perception of the topics. The validity of the questionnaire was examined by a science education expert. The questionnaire was piloted on four teachers, two from CSS and two from CDSS.

The population of the study comprised all Biology teachers in public secondary schools in Zomba. There are 26 public secondary schools in Zomba, of which 9 are CSSs and 17 CDSSs. All CSSs participated, and 11 from the 17 CDSSs were randomly selected. Questionnaires were administered to Forms One and Two Biology teachers in the 20 schools (40). Of these, 32 teachers completed the questionnaires, representing 80% response rate. Quantitative parts of the questionnaires were entered into a spreadsheet and results compared for the two categories of schools using frequencies and students’ t tests where applicable. Qualitative parts were analysed qualitatively by looking for recurring themes.

Results of the study

Outside support

Table 1 presents the frequencies of syllabus, textbooks and teacher’s guide availability, teacher orientation and supervision.

<table>
<thead>
<tr>
<th></th>
<th>CDSS n =18</th>
<th>CSS n =14</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syllabus</td>
<td>56</td>
<td>93</td>
<td>72</td>
</tr>
<tr>
<td>Textbook: Strides in Biology</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Teacher’s Guide for Strides in Biology</td>
<td>50</td>
<td>43</td>
<td>47</td>
</tr>
<tr>
<td>Textbook: New Junior Biology</td>
<td>56</td>
<td>93</td>
<td>72</td>
</tr>
<tr>
<td>Teacher’s Guide for New Junior Biology</td>
<td>5</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>Orientation to New Syllabus</td>
<td>22</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Orientation to New Topics</td>
<td>11</td>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td>Supervision</td>
<td>50</td>
<td>29</td>
<td>41</td>
</tr>
</tbody>
</table>

The results in Table 1 show that not all teachers had the new syllabus, textbooks and teacher’s guide. Furthermore very few were oriented to the new curriculum and topics. Supervision of teachers was rather low. Outside support to a school implementing a new curriculum in Malawi would mainly be provided by the Ministry of Education at central government and division level. The kinds of support are provision of syllabus, textbooks, teachers’ guide, orientation to the new syllabus and the teaching of new topics, and supervision in form of inspection and advisory services. At basic level for textbooks it is expected that at level one that all teachers would have a full complement of syllabus, recommended textbooks and teacher’s guide and supplementary materials. At a second level a school should have enough copies of recommended textbooks in order to organise classroom activities using them. At higher levels there should be adequate supplementary textbooks for teachers to use in lesson preparation. From the results it would seem that only very few of teachers reported to have been at the basic level.

The second aspect of Outside support would be how much help do teachers get from the textbooks? The New Junior Certificate Biology and Strides in Biology are recommended
books for Junior Certificate in Education (JCE). *Strides in Biology* books were purposely written for the new syllabus and contain extensive sections that address all the objectives in the syllabus. *The New Junior Certificate Biology*, an adaptation of a previous book to the new syllabus, has a short section comprising two chapters that address 8 out of 24 objectives of the new topics. 39% CDSS teachers and 57% CSS teachers said the textbooks treated the new topics adequately. Those who said textbooks are not adequate indicated that they needed more information in order to make notes for the learners.

The third aspect of Outside support is provision of continuing profession development (CPD). It is expected that the Malawi Institute of Education (a curriculum development centre) would orient all teachers to the new syllabus the teaching of the new topics in order to get them started in implementing the new curriculum. This would be followed by Ministry of Education’s support for schools to do school based In Service Training (INSET) to enable to plan together and support each other in implementing the new curriculum. In this way they will be able to eventually review the instructional materials and develop their own. The results indicate that few teachers attended orientation workshops for the new curriculum and topics and there were no indications of school based INSET. The work of Rogan and Grayson (2003; 2007) has shown that orientation of teachers and school based CPD are critical in implementing curriculum change. It would seem this aspect has been neglected in Zomba. In most cases some teachers are trained at training workshops but fail to implement school based INSET because of lack of outside support at this level. The final category is in monitoring and evaluation in terms of inspection and supervision was hardly done.

**Capacity to innovate**

**Teacher and school characteristics**

CDSSs have no laboratories, whilst CSSs have. Furthermore, CDSSs have less qualified teachers than CSSs (See table 2). For example, in CDSSs there are 33% teachers not qualified to teach in secondary school, whilst in CSSs all teachers have basic qualifications. However 61% CDSS and 71% CSS teachers felt qualified to teach the Biology.

The construct of Capacity to Support Innovation mainly focuses on school factors. This study focussed on availability of laboratory, class size, teacher qualifications, experience and teaching load. It would seem that the Capacity to Innovate for CDSS is very low, with no laboratories, 33% of teachers underqualified. On the hand CSS have better Capacity to Innovate with laboratories and better qualified teachers. In Both types the class sizes are generally large, which would pose a challenge in teaching the new topics which require active learning approaches. Teacher’s experience is medium and this may make them as easily amenable to change.

**Table 2 Teacher qualifications**

<table>
<thead>
<tr>
<th>% Teachers</th>
<th>CDSS n =18</th>
<th>CSS n =14</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSCE and Primary Teacher Certificate</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>Diploma in Education</td>
<td>28</td>
<td>36</td>
</tr>
<tr>
<td>Degree in Education</td>
<td>39</td>
<td>64</td>
</tr>
</tbody>
</table>

**Table 3** compares Class size, Teaching load and experience in CDSS and CSS. The class sizes, teaching loads and experience are similar in the two types of schools.

**Table 3: Class size, Teaching Load and experience**

<table>
<thead>
<tr>
<th></th>
<th>CDSS n =18</th>
<th>CSS n =14</th>
</tr>
</thead>
</table>

296
Implementation profile
In this section the teachers were asked to rate how easy or difficult the new topics were to teach. They were also given opportunity to indicate if they had not taught the topic or attained the objectives. Table 4 gives the results.

Table 4: Teacher’s perception of the topics

<table>
<thead>
<tr>
<th>Objective</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thinking skills</strong></td>
<td></td>
</tr>
<tr>
<td>Present data in tabular and graphic form</td>
<td>17</td>
</tr>
<tr>
<td>Recognise variations amongst organisms of the same species</td>
<td>5</td>
</tr>
<tr>
<td>Summarise biological data in terms of bar charts, histograms, means, median and range</td>
<td>6</td>
</tr>
<tr>
<td>Explain the importance of sampling in Biology</td>
<td>5</td>
</tr>
<tr>
<td>Identify Variables</td>
<td>17</td>
</tr>
<tr>
<td>Recognise irrelevant variables in given data</td>
<td>28</td>
</tr>
<tr>
<td>Deduce correlational relationship between variables</td>
<td>28</td>
</tr>
<tr>
<td>Deduce mathematical relationships</td>
<td>28</td>
</tr>
<tr>
<td>Suggest explanations for observed relationships</td>
<td>39</td>
</tr>
<tr>
<td>Recognise that large samples give better representation</td>
<td>17</td>
</tr>
<tr>
<td>Use mathematical relationships or graphs to make predictions</td>
<td>50</td>
</tr>
<tr>
<td>Design experiments with proper control</td>
<td>55</td>
</tr>
<tr>
<td>Deduce qualitative relationships</td>
<td>33</td>
</tr>
<tr>
<td>Formulate hypothesis to test suggested explanations</td>
<td>50</td>
</tr>
</tbody>
</table>
Thinking skills
Generally, more teachers in CDSS indicated that they found these topics difficult than teachers in CSS. The following objectives were rated easy by teachers from both types of schools: identify variables, present data in tables and graphs, deduce mathematical relationships between variables, suggest explanations for observed relationships, recognise variations in organisms, summarise biological data in terms of means, median, range, charts and histograms, recognise the importance of taking samples. All these objectives are encountered frequently, especially in mathematics. Therefore, one would expect them to be easy as both teachers and learners would have plenty of experience. The concepts that deal with biological data (variation, sampling and describing distributions), though perceived to be easy by both groups of teachers had not been taught by many. This is not surprising as they are not commonly done in most secondary curriculums and get introduced in statistical courses at tertiary level (Mbano, 1990). More teachers in CDSS indicated that they found the teaching of objectives ‘making prediction,’ ‘formulating and testing hypothesis,’ and ‘designing investigations’ difficult than teachers in CSS. It may be that teachers in CDSS, being less qualified find these objectives difficult because they are not familiar with investigations. Overall ‘correlation,’ ‘design investigations,’ ‘formulate and test hypotheses,’ sampling,’ were recorded as not taught by most of the teachers.

Study skills
The two objectives on study skills; summarise information from books, and to describe specimen using well labelled diagrams were rated as easy by both groups of teachers. Furthermore, the number of teachers who had not taught was small. It would seem teachers are confident about teaching this topic. However the objectives on judging statements, such as whether they were factual or opinions, recognising assumptions in statements and giving evidence for assertions had not been taught by many teachers from both types of schools.

Investigative and problem solving skills
The two objectives in investigative skills: carry out investigations and write reports are reported easy and generally taught by CDSS teachers. Problem solving skills, although rated easy by both group of teachers, more CSS teachers do not teach it than CDSS teachers.

Teachers’ perceptions of the value, difficulties and learners’ response
The questionnaire had an open ended section asking teachers what they saw as the value of the new topics, difficulties they experienced in teaching it, and suggestions for improvement. Table 5 gives the frequency of categories of the responses
Many teachers saw the value of the new topics as “Deals with real life situations”, assisting in understanding and acquisition of skills. There was not much consensus on the value of these new topics such that it seems each teacher creates his own value. This may be symptomatic of lack of knowledge and experience in the topics, which point to lack of orientation. It also means that the teaching varied from teacher to teacher, depending on their perception. Table 6 gives results of how the teachers felt about teaching the new topics.

Table 6  How teachers feel about teaching the topics

<table>
<thead>
<tr>
<th>Perception</th>
<th>CDSS (n =18)</th>
<th>CSS ( n =14)</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficult, involving</td>
<td>44</td>
<td>14</td>
<td>31</td>
</tr>
<tr>
<td>Good and interesting</td>
<td>17</td>
<td>36</td>
<td>25</td>
</tr>
<tr>
<td>Too much content</td>
<td>11</td>
<td>28</td>
<td>19</td>
</tr>
<tr>
<td>Not interesting</td>
<td>0</td>
<td>36</td>
<td>16</td>
</tr>
<tr>
<td>Not biology</td>
<td>0</td>
<td>28</td>
<td>13</td>
</tr>
<tr>
<td>Important, helpful</td>
<td>5</td>
<td>21</td>
<td>13</td>
</tr>
<tr>
<td>Confident</td>
<td>5</td>
<td>14</td>
<td>9</td>
</tr>
</tbody>
</table>

There was more negative perception of teaching these topics, with comments such as “difficult, involving, too much work, not Biology, lack of teaching and learning resources”, and “not interesting” accounting for 44% of the responses, whilst positive comments such as “good and interesting, important and helpful, confident, have knowledge”, and “easy” making up about 26% of comments. Some perceptions separated teachers in CDSS from teachers in CSS; for example, 36% of teachers in CSS found the topics “not interesting /boring”, whilst none of the teachers in CDSS stated this. 44% of teachers in CDSS found them “difficult to teach” whilst only 14% of the teachers in CSS mentioned this. 28% of the teachers in CSS complained that there was “too much content for the allocated time”, but only 11% of the teachers in CDSS said this. 44% of the teachers in CDSS teachers mentioned “lack of resources”, but none of CSS teachers indicated this. 44% of the teachers in CDSS said that their “learners find them difficult because they are slow learners and are unfamiliar with the situations”.

It would seem most of these differences are a reflection of what obtains in the schools. CDSS teachers operate in more poorly resourced schools, such as with lack of laboratories, with poor qualification, and slower learners who scored lower marks in the Primary School Leaving Certificate (PSLC) examinations. With such negative attitude to their learners’...
ability, one wonders how much of what goes on in CDSS and student achievement is not as a result of this self fulfilling prophecy.

More than 50% of the teachers felt that the Ministry of Education (MOE) should provide more resources and orientation for the teachers. Some suggested that the new topics should be integrated with regular Biology topics by spreading them throughout textbooks. Furthermore, they suggested that activities should be relevant to learners’ experience and previous knowledge. In addition, the topics were seen to be too long and to take too much time. Accordingly, there were suggestions to reduce them, both in the syllabus and in textbooks by leaving out some objectives such as judging statement which are seen to belong to English.

Using Profile of Implementation (Rogan and Grayson, 2003) it is rather difficult to fit the two groups of teachers into levels. Teachers in CDSS seem to be at the level of Mechanical and Routine use, as are attempting to teach all the topics. Teachers in CSS, on the other hand, may either be at the preparatory stage where they are still finding out about the new topics and not teaching or at refinement and integration stage where they choose and pick which topics to teach according to their needs and context. The comments on how the teaching could be improved show that the teachers have good ideas on how to implement the curriculum taking into account their needs and contexts. This highlights to the importance of school based INSET where such ideas could be put to use.

Discussion
The study reveals several weaknesses in the implementation process using the theory proposed by Rogan and Grayson (2003). Firstly there seems to be weak Outside Support and Capacity to Innovate leading to low level of Profile of Implementation. With regards to Outside Support, not all learning materials were available to teachers and learners. Furthermore there was no appropriately planned CPD. Rogan and Grayson’s work has revealed that school based INSET achieves better outcomes than externally managed CPD (Rogan and Grayson, 2003). Furthermore they have developed the concept of ZFI which seems also to work well at school level, as teachers can take into account both context at the school and current practices. The school factors to support innovations are very weak in CDSS with poorly qualified teachers, no laboratories and learners with poor achievement at primary school level. Although teachers worked hard to implement the curriculum their efforts were frustrated by lack of support both in school and externally. CSS have better in school capacity to innovate, however their implementation is hampered by lack of school based implementation plans..

Limitations of the study
This is a case study was limited to Zomba schools; hence the results cannot be generalised to other areas. The use of questionnaires limits the depth of information that can be collected on teachers’ experience in teaching the new topics.

Implications of the study
The study using Rogan and Grayson (2003) Theory for Curriculum Implementation suggests that schools in Zomba had low implementation profile because of low Capacity to Innovate and poor Outside Support. It would seem that the main constraint was inadequate support in terms of instructional materials and CPD. Although work in curriculum implementation point to the importance of school based CPD there was no evidence of any plans or activities in this. In order to authentically implement a new curriculum there is need to invest in physical resources, instructional material and CPD.
References


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I am greatly indebted to the teachers who took part in the study. I am grateful to the National Research Council of Malawi for funding the project and Faculty of Education, Chancellor College, University of Malawi for assisting with transport.
An evidence-based findings of the effects of active teaching and learning methods on a large and under-resourced primary school science class

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Abstract

This paper reports part of the findings of a small study that was conducted in the process of undertaking an intervention. Some of the aims of the interventions were to determine the effects of active teaching and learning approaches on influencing children’s creativity in the development of teaching and learning materials in a large and under resourced science and technology primary school class in Malawi. Key idea sentences/explanations and cloze procedures were used to teach a standard 7 class by one of the authors for a period of 10 weeks. Before teaching each of the five topics, a pretest was given to the learners to assess their level of understanding of the topic and after teaching a similar test was given to the learners in form of a post test. The same was done with the control group. Four data collection methods were used to collect data thereby making use of both quantitative and qualitative research methodologies. While the pre and post tests served as quantitative methods, focus group discussions and classroom observations served as qualitative methods. The findings demonstrate with broad strokes that active teaching and learning techniques has an influence on the learners creativity as demonstrated by several inventions and the development of the learners own teaching and learning resources. Therefore, this paper will highlight the learner’s creativity in the development of the teaching and learning materials and implications of the findings for teaching in Malawi primary schools large and under resourced classes so as to ensure and promoting access to socially responsible mathematics science and technology education.

Introduction

The study was conducted by one of the authors at a primary school in Malawi. The study involved an intervention. In the course of the intervention data were collected. One of the aims was to determine whether active teaching and learning techniques that have been advocated in the literature, and were used in the intervention, could influence children’s creativity in the development of teaching and learning materials in a large and under resourced science and technology primary school class at Matiya Primary school.

The intervention and study were carried out as part of the SUSTAIN project. The purpose for SUSTAIN project is to seek ways of promoting a socially responsible science and technology education for learners in different countries especially those of Sub Saharan Africa. From the discussions within the project team, a number of descriptions emerged and are hereby summarized and reproduced for clarity and these specifically refer to this presentation - a socially responsible SMT education would:

a) Echo the needs of the pupils, be creative, and teach pupils to become creative;
b) Provide democratic spaces for learning;
c) Enhance conceptual understanding, as well as the ability to take action;
These descriptions are in line with what Kyle (2006) drawing upon Habermas, (1972), described concerning a socially responsible SMT education. He described this as an education that focuses both on developing learners' technical knowledge interests, where the aim is to understand nature, and on their emancipatory knowledge interests, where they learn to act and change their environment.

The aspect that will be the subject of this presentation will be to explore whether the use of active teaching and learning techniques could enhance learner creativity in the as evidenced by the development of teaching and learning materials.

**Active teaching and learning approaches**

Active teaching and learning approaches have been advocated for the teaching of science for a long time. This is because of the large number of challenges associated with science and technology teaching and learning including abstract concepts and irrelevant content especially for Africa (Peacock, 1995) and lack of materials for practical work (Nampota, 2009) especially in large classes. While early discussions on active teaching and learning approaches concentrated on inquiry (for example Dewey), in the early 1990s, more specific approaches were recommended. Osborne (1993) for example advocated for use of paper and pencil activities such as concept maps and Directed Activities Related to Reading Text (DARRT) in order to enhance learning. While concept maps concern making relationships among concepts and sub-concepts in diagrammatic form, DARRT activities help learners think and read about a text in different ways. Examples of DARRT activities are; key idea sentences or explanations, comprehension exercises, word burrs and cloze procedures (Osborne, 1993). Although the DARRT activities were recommended specifically in relation to teaching practical work in the absence of equipment, in recent years they are related to the thinking about learner centred teaching and learning approaches. Learner centred teaching and learning approaches are at the centre of the new Science and Technology syllabus for primary schools in Malawi. The new curriculum, which is outcome, based is being implemented under the banner of Primary Curriculum and Assessment Reform (PCAR) introduced in 2005. In this curriculum, teachers are encouraged to use learner centred teaching and learning approaches. An analysis of this curriculum implementation however shows that group work is perceived to be the main learner centred approach and is recommended in the curriculum materials (Government of Malawi, 2001). Within the group work, teachers are supposed to use techniques that enable learners interact with each other and the content. Some of the recommended techniques include use of flask light but requires a lot of resources such as felt pens, chart paper, soft boards and prestik and these are usually not available in the schools.

On the contrary, most of the DARRT activities are paper and pencil activities which would not require a lot of resources. It was for this reason that DARRT active teaching and learning techniques were tried in one class at a primary school in Malawi in order to explore whether they could be used to enhance learner creativity as demonstrated by the work that learners produced in large classes of over 70 learners.

**Assessing effective teaching and learning in the context of large classes**

The key word describing the efficiency of teaching and learning is education quality. A review of literature has shown that defining education quality has been a challenge to many
educators, perhaps as a result of the many elements that influence it. UNICEF (2000) however put forward five dimensions of education quality that have been widely used. These are:

a) Quality of learners – including regular attendance for learning.
b) Quality of learning environments – includes school facilities, school infrastructure, class size and safe environment.
c) Quality of content – in terms of the actual knowledge and skills that learners should acquire.
d) Quality of processes – professional teachers, using appropriate teaching and learning approaches.
e) Quality of outcomes.

Within the context of the school that the researchers for this study worked in, quality of the learning environment were defined by features such as a large class (91 learners) with limited resources. The interest for the study was thus on the quality of processes that take place in the classroom in the stated context and quality of outcomes. It was of interest to determine whether or not use of active teaching and learning techniques could influence learner creativity resulting in better achievement in the learners especially for areas that require learner comprehension of concepts. The processes associated with learner centred approaches are best explained using the theory of constructivism which was used as a guiding framework for the research study.

**Conceptual framework for the study**

Constructivists argue that learning is an active process in which the learner uses sensory input and constructs meaning out of it (Driver, 1993, Driver 1989; Champagne et al; 1983). The more traditional formulation of this theory involves the terminology of the active learner stressing that the learner needs to do something in the teaching and learning situation that learning is not the passive acceptance of knowledge which exists "out there" but that learning involves the learner engaging with the world.

It also has been advanced that learning is a social activity. Learning is intimately associated with the connection with other human beings - teachers, peers, family as well as casual acquaintances, including the people before or next to the learners. Teachers are more likely to be successful in their efforts to educate learners if they recognize this principle rather than try to avoid it. In this study, the interest was to explore whether use of active teaching and learning approaches in the ‘learning process’ could help attain constructivist learning principles in a standard 7 classroom Furthermore, the study explored whether or not the constructivist learning principles resulted in more meaningful learning and therefore improved attainment of learning objectives as evidenced by the creative work that emanated from the learner work.

**Methodology**

The study involved both an intervention and a research component. These are described briefly.

**a) The intervention**

The intervention took a period of ten weeks where the teacher taught a standard 7 class comprising 91 learners using two active teaching and learning techniques – key idea
sentences or explanations and cloze procedures. The third technique was to use a nature table. The topics for the intervention were not pre-selected but the teacher followed the scheme of work that the previous teacher for the class had prepared. The topics that had to be taught in the ten weeks were five – Properties of Light, Heat, Sound; Forces; Machines; Tie and Dye and Growing Up. The learners were placed into eleven permanent groups with rotational group leaders, materials managers, recorders and time keepers. The teacher gradually introduced the three learning techniques to the whole class first and then to small groups. Due to insufficient materials, each group was responsible for collecting its own materials or resources for learning and this had to be arranged in advance. In addition, learners were asked in advance to go and read or ask more about what would be taught.

At the beginning of each topic, learners were given a pretest on key aspects of the topic. After teaching each of the topics, a similar test was given to the learners as a post test. This was done for all the five topics that were taught. As they work towards producing teaching and learning materials, focus was also turned towards the quality of the work produced and their articulation of the concepts.

b) The research
The research component made use of both qualitative and quantitative methodologies due to the nature of data sought. The nature of data for the ‘process’ component necessitated use of qualitative research methodology. The qualitative approach was favored because of the opportunity it provides for the researcher to describe an event in the social world from the standpoint of individuals who are part of an ongoing event (Cohen & Manion, 2000). The learners not only took part in the intervention, but their expectations and reflections gave meaning to the intervention. Five Classroom observations, ten individual interviews and eleven focus group discussions were used to collect data. The questions for the FGDs and interviews focused on the learners’ views of the active teaching and learning techniques used during the intervention and how they enhanced their learning of science and technology.

Quantitative data was collected through the use of pre and post tests that were given at the beginning of a topic and after the topic had been taught. This was done in order to determine the possible impact of use of active teaching and learning techniques on learner construction of meanings and therefore performance. Mean scores of pre and post tests for each of the topics were compared to determine whether there were differences. These are reported below on Table 1 below:

<table>
<thead>
<tr>
<th>Topic</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std Dev</td>
</tr>
<tr>
<td>Properties of Light,</td>
<td>13.57</td>
<td>3.58</td>
</tr>
<tr>
<td>Heat and Sound</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forces</td>
<td>18.05</td>
<td>6.02</td>
</tr>
<tr>
<td>Machines</td>
<td>20.68</td>
<td>5.10</td>
</tr>
<tr>
<td>Tie and Dye</td>
<td>23.23</td>
<td>9.70</td>
</tr>
<tr>
<td>Growing Up</td>
<td>34.46</td>
<td>7.13</td>
</tr>
</tbody>
</table>

Qualitative data were analyzed through repeated readings of the transcripts and coding them according to the categories of the framework. The categories and subcategories were worked out and are presented in the findings section.
Findings
The findings of the study are presented in two parts which address two general issues: (i) effect of the teaching approach on learners’ performance, and (ii) effect of the teaching as evidenced from the produced (creative) work and effect of teaching approach on learning process.

Effect of the teaching approach on learners’ performance
Concerning performance, results of the tests of all the five topics showed increases in the means from the pre test to post test (see Table 1). There was also increase in the minimum and maximum scores for all the topics. For example, on the topic of Properties of Light, Heat and Sound, the mean increased by 14, while the minimum and maximum scores increased by 6 and 23 respectively. This indicates that, performance in the post tests increased for most of the learners. However, the standard deviation and the range also increased indicating that the spread of scores was wider in the post test than in the pre test.

The improved performance of the learners after instruction should however not be attributed to the use of the active teaching and learning techniques alone. Many other factors may have played a part. For example, the teacher was different and was new at the school. Furthermore, the fact that the learners were assessed before and after being taught is likely to lead to improvement in their performance. As such what the findings show is that active teaching and learning techniques have potential to enhance the effectiveness of group work which is taken as the main learner centred approach in the curriculum materials. The actual contributions of the techniques to effective learning were described in the qualitative findings as will be discussed in the section that follows.

Effect of teaching approach on learning process
The effect of the active teaching and learning approaches on learning process were categorised into five categories which are not mutually exclusive: participation, creativity, collaboration, discipline and understanding. All names are pseudonyms and not real names of learners.

Participation
In general and perhaps as would be expected, the active teaching and learning approaches enhanced learner participation in lessons both during the class sessions, outside the classroom and during nature table activities. In all these, learners enjoyed the aspect of bringing materials to school, for example one learner Chifundo said:

“Zimandisangalatsa ndizakuti timabweretsa zinthu zophunzilira” (What I liked about the lessons was the opportunity to bring materials to class that could be used for our learning).

And as the learners were discussing key idea sentences or cloze procedures, they learnt how to defend their own answers both within their groups and to the whole class when their group results were being compared with those of other groups. They also learnt to ask questions. The following quote from the reflective journal of the teacher exemplifies this:

“In the class, we observed the learners’ ability to initiate and reasonably contest some issues they felt were not being properly understood. They constantly asked questions for clarification. They had the ability to ask follow up questions” (Teacher’s journal entry).
For instance, when the topic on properties of light was being taught, learners asked the teacher to demonstrate whether light travels, because according to them, at that time, *light just shines*. They never thought that light travels. When it was demonstrated using a holed bamboo (which was brought by the learners) that ‘Light travels’.

**b). Learner creativity and other skills**

Learner involvement in various activities led to learners developing creativity and other manipulative skills. For example, the learners invented a version of a bottle opener using a nail and a small plank. Learners’ creativity was demonstrated when various devices that use the application of scientific concepts applied in every day were produced as can be seen from tables 2.

<table>
<thead>
<tr>
<th>Table 2: Properties of light</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Topic</strong></td>
</tr>
<tr>
<td>Light</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
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<tr>
<td></td>
</tr>
</tbody>
</table>

**Making, explaining the use of the following technologies:**

**Simple microscope**

Learners were able to collect materials like wires, small sheath of tin, old magnifying glass from an old camera. Then learners without following a particular pattern produced a microscope with an adjusting knob that was able to make small objects look big. Here is what some of them said;

’Yes ...look.A grasshoppers head...looks very big!!’ Commented Alfundi.

Then there was a struggle for each member of the group to have a turn to use the microscope and then learners were asked to collect water in a transparent freezit plastic container and attempt to see whether it was possible to see a small object looking big. When the group tried, this was followed by jeers of: ‘Eti....no it cannot be.....’

What was pleasing was that these experiments were being conducted outside the classroom. And as the learners were working and explaining their findings, members from the community gathered not to disturb but to appreciate what was going on.

When learners were asked as to what property of light was being used to make things look big. They ably responded ‘Refraction’

**Pinhole camera**

This one though common, learners took time to really figure out how make it and how the object was to appear on the screen. It took them four lessons to figure out how to make a pinhole camera whose object was going to appear upside down.
After working out here are some of their comments.

“Oh..i did not know that the object will look upside down..This is not true. How can true in an upright position look upside down?’

When asked to explain why the object appeared upside down, most of the learners were able to say that it was because light travels in straight line. This explanation sparked a lot debate.

‘How can it be that when an object is looking upside down then we can say that light travels in straight-line..Why can we not say that it travels upside down? Some learner’s retorted.
When a diagrammatic representation of the pinhole camera was drawn learners still had reservations. They strongly felt that light does not travel in straight line. It was very difficult to prove them that light travels in straight line up until the lesson was repeated.

Periscope
Learners were asked to produce a device that can enable short learners to see objects that they cannot see because of height by using a cardboard and mirrors.
This activity also took most of their time. They were however guided on how to figure out and when they finally discovered the arrangement of the mirrors and how they reflect the objects from the other side, it’s when they grew in their enthusiasm.
‘Sir, come and see how it works!’ One learner invited the teacher.

‘Yes I can see the goats going into the bush from the other side of the school, ’retorted Maya

Table 3: Properties of sound

<table>
<thead>
<tr>
<th>Topic</th>
<th>Properties of sound investigated</th>
<th>Making technologies that use properties of Sound</th>
<th>Using the technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound</td>
<td>Sound can be transmitted</td>
<td>Made musical instruments , drums, guitar, and wind instruments</td>
<td>Played the musical instruments and explained how they work. Stated the properties of sound the technologies use.</td>
</tr>
<tr>
<td></td>
<td>Sound can be absorbed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sound can be reflected</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sound travels in all directions</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sound travels through states of matter</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The making of drums, guitar and flutes from bamboo and reed seemed and looked to be easy, however the production of flutes is what this section will be interested in. Learners had to organize themselves to go and find out from home how indigenous wind instruments were made.
‘Guys we have to find out from home’. They advised each other.
From home they were advised to find a wasp’s membrane and that using reed or gourd they were to drill a hole and spare one section where they were going to be blowing and one end stick the reed just with saliva and let it dry and try to blow.

‘Yes. the sound is like that of the Malipenga dancers…very nice…’ commented Lucia.

Learners took turns to test their musical instrument
When asked how sound was being produced, they were able to explain that it was by blowing.

**String telephone**
This was the easiest and this did not consume much of the learners time. However, to challenge them the more, they were asked to work on different sizes of strings, length of the string and nature of the tin, to ascertain whether they affect the loudness.

**Figure 2: A string Telephone**

![String Telephone Diagram]


**Table 4: Properties of heat**

<table>
<thead>
<tr>
<th>Topic</th>
<th>Properties of heat investigated</th>
<th>Making technologies that use properties of heat.</th>
<th>Using the technologies and explained how they produce sound.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat</td>
<td>Heat can be transmitted</td>
<td><strong>Made solar box cooker.</strong></td>
<td>Practicing using the technologies and explained how they produce sound.</td>
</tr>
<tr>
<td></td>
<td>Heat can be absorbed</td>
<td><strong>Made a working model of a solar geyser.</strong></td>
<td>Stated the properties of heat the technologies use.</td>
</tr>
<tr>
<td></td>
<td>Heat can be reflected</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heat travels</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heat travels through the states of matter at different speeds</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

On properties of heat, learners were asked to find out the application of heat is being used in the home and from there develop models to explain how the devises work.

**Solar box cooker.**
The teacher obtained information from the internet and provided it to the learners. The
learners found out that it was the easiest, most sensible, and most affordable to make solar powered oven. All it required was two cardboard boxes (one inside of the other), an acrylic cover, black paint, and silver foil. With the boxes inside each other, the box on the inside painted black and the box on the outside covered in silver foil, they created an oven beneath the acrylic cover. The box got hot enough to cook sweet potatoes, bake bread, potatoes, and cassava and boil water.

The learners didn't invent solar box cooker but did help to publicize them ‘I will make one at home for my family’. Angela commented.

Table 5: Properties of energy and machines

<table>
<thead>
<tr>
<th>Topic</th>
<th>Properties of Energy and Machines investigated</th>
<th>Making technologies that use the properties of Energy and Machines</th>
<th>Demonstrating using the technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force</td>
<td>Forces can:</td>
<td>Making wire toys / plastic balls/pulleys/</td>
<td>Practising using the technologies made, collected and using them</td>
</tr>
<tr>
<td></td>
<td>Cause and acceleration</td>
<td>Collecting magnets and demonstrating forces of attraction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Speeding up</td>
<td>Using cardboard to demonstrate that</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slowing down</td>
<td>Force can change the shape of an object</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Change direction</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Do nothing</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cause work (w = Fd)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Change shape</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Making wire toys, plastic balls and pulleys

Wire toys
Learners made wire toys of cars and demonstrated how force makes it move and stop

![Figure 3: A wire toy](#)

Plastic balls
They collected plastic paper and produced balls which they demonstrated how force make them stop moving or make them move.
The pulley system was set up as shown in the diagram. Attached to it were the force meter to the free end of the cord and a $\frac{1}{2}$ kg load to the lower pulley. Learners Pulled on the cord with the force meter. Measured how far the load rises, and how far the force meter end of the cord travels, for the same pull. They noted that the force measured by the force meter when pulled is just hard enough to get the load rising.

Learners were able to note that, machines are force multipliers and also are able to show that machines do not multiply energy. Lastly at their level they were able to find out that a pulley makes work easier by redirecting force. For example, a pulley hanging from above allows pulling down on a rope to convert into an upward force on the load.

**Lever**

Learners found out that Levers are one of the basic tools that were probably used in prehistoric times. Levers were first described about 260 BC by the ancient Greek mathematician Archimedes (287-212 BC). Learners found out that, a lever is a simple machine that makes work easier for use; as it involves moving a load around a pivot using a force. Many of our basic tools use levers, including scissors (2 class 1 levers), pliers (2 class 1 levers), hammer claws (a single class 2 lever), nut crackers (2 class 2 levers), and tongs (2 class 3 levers).

**Table 5: The three classes of levers**

In a first class lever learners observed that, the pivot (fulcrum) is between the effort and the load. In an off-center type one lever (like a pliers), the load is larger than the effort, but is moved through a smaller distance.
After learning and using the various lever machines, learners invented a new version of a bottle opener using a nail and a small plank. This was observed when they were making various machines and then demonstrating how they simplify work.
As they produced the various materials it was observed that active teaching and learning approaches improved class communication between the teacher and the learner. For example, classroom observations at the beginning of the intervention showed most of the learners had problems in understanding the English language there by contributing to their dismal participation in class. As a result of the continued use of the active teaching and learning learners’ basic understanding of the English language and therefore their communication improved greatly. Increased level of class contribution, participation and performance were observed with time. In addition, the overall quality of discussion and reporting improved a great deal.

**Collaboration**

Collaboration between teachers and learners and among learners themselves was seen as one opportunity that was offered by use of active teaching and learning techniques in enhancing access to the topics.

In addition to collaborating with the teacher, the learners also collaborated within their own groups as it was not necessary for all of them to bring the same materials at the same time. This enabled them to connect with what they were learning in class and that from outside the classroom. During an interview with Mphatso, he said:

“Timagawana ntchito ndikuuzana zakuti aliyense abweretse. Zimayenderanso ndi topic yake kuti angapeze zinthuzo ndani” (We shared roles in terms of who should bring what and when. It all depended on the topic under study and choosing learners who would have access to the materials required)

Overall, it was found that though the class was large and under resourced, the collaborations enabled the availability of adequate teaching and learning resources for all the eleven groups.

**Discipline**

The teacher noted that there was improved learner discipline as the lessons progressed:

“At the time we started teaching, there were a lot of discipline issues. Previously the level of engagement was dismal” (Teacher’s journal entry).

What this means is that the approaches meaningfully engaged learners. Learners were always busy and there was no room for learners to sit idly and make noise. The result was the improved discipline.

**Relevance**

As the learners were looking for materials to bring to class as requested by the teacher, learners had opportunities to extend the science ideas learnt in class to outside the classroom thereby enhancing their understanding as well as making connections between school science and the science in their community. This was evident especially during learning of the concept of nature table. As one learner Yamiko said:

“Pamene timakafuna zotenga kusukulu, anthu amatifunsa kuti ndizachiayani ndiye pofotokoza timakumbukira zomwe tinaphunzira mukalasi” (When we went collecting materials, people asked us what they were for and we explained. This helped us remember what we were being taught in class).
Seeing these connections between classroom and outside classroom science helped learners appreciate the relevance of what they were learning in class to the materials they were collecting.

**Understanding**
During interviews, most of the learners attributed their improved participation in class and performance to the active teaching and learning approaches. They found learning science and technology easier and more interesting than before. For instance, Khama, and Mavuto the following to say when asked what he felt about the method:

“Science ndi technology siyikuvutanso kuphunzira ndipo masiku ano ndikuitha” (Learning Science and Technology is easy now and am able to do Science) Interview with Khama.
“Poyamba Science ndi technology imandivuta koma pano bola chifukwa ndikumapanga zinthuzo ndekha” I used to find learning science and technology difficult but now it is better because I am doing things to find out myself” Interview with Mavuto

“Ine pano ndili ndi mwai wopanga nawo ma experiment zomwe zindinapangepo” (I now have the chance to do experiments and I take part. I was not able to do this before)

Several aspects can be discerned from the quotes that could help explain what might have led to improved understanding and performance of the learners. The first is the ability for learners to take an active role in the learning process so that they take responsibility for their own learning. The second is to find out things on their own and not always being told by the teacher.

In addition to the two aspects, learners mentioned the good learning environment that was established by the teacher and this approach as one contributing factor to the improved participation and hence understanding. Limbani had this to say:

“Timakhala omasuka kunena maganizo athu mopanda mantha kuti mwina ndizolakwa” (We are free to express our ideas without fear that we will be giving “wrong” answers) Interview with Limbani.

Among the various skills that the learners acquired are reasoning skills since they had to learn to justify their solutions or defend their own viewpoints during class discussion.

“Timayenela kupanga defend ma answers a gulu lathu kwa ena onse mukalasi, makamaka zikakhala za key ndi cloze. Zimatipangitsa kuti tiganize” (We had to defend our answers as a group to the rest of the learners especially for key idea sentences and cloze procedure activities and this helped us to think. Interview with Luso

Overall, it appears that it was the combination of all the learning opportunities that the active teaching and learning approaches provided that contributed to the enhanced participation and improved performance demonstrated.

**General discussion**
As observed in this presentation the objectives of project SUSTAIN included finding ways of teaching mathematics, science and technology that are socially responsible. This study focused on three of the eight aspects mentioned in the introduction, which are: echo the needs of the pupils, be creative, and teach pupils to become creative; provide democratic spaces for learning; and enhance conceptual understanding, as well as the ability to take action.
The findings of the study demonstrate that these three aspects are achievable by using active teaching and learning approaches. Although the study was limited to a period of ten weeks and five topics of Science and Technology, the findings can be applied to other topics in Science and Technology as well as Mathematics. Similar to Science and Technology, Mathematics requires conceptual understanding which is difficult to achieve through the traditional chalk and talk teaching method. Using active teaching approaches would help enhance learners’ conceptual understanding, participation in class and interest in the subject as was observed in this study for Science and Technology. Conceptual understanding of mathematical and scientific concepts enables learners to succeed in the subjects and study the subjects’ further thereby increasing student participation in SMT subjects at the higher levels of education. Conceptual understanding also enables learners to apply their understanding to real life situations in their community and environment.

It was observed and confirmed by the learners that the approach provided democratic learning spaces for the learners. This was due to the nature of the approach which created ‘freedom’ to learn. Therefore the study achieved aspect 5 which is important for socially responsible MST education. The findings of the study have also demonstrated improved reasoning skills and creativity in the learners. This is another important goal of socially responsible MST education and it speaks directly to aspect 4 as listed in this presentation. Mathematical and Scientific reasoning is enhanced by conceptual understanding of the topics under study, and similarly, conceptual understanding improves reasoning. Creativity, reasoning and conceptual understanding are all integrated. While democratic learning spaces provide learners with the opportunity to learn freely, share their ideas, ask questions, and engage with other learners. Therefore the development of the three aspects as was done in this study would contribute to the development of some or all of the remaining five aspects.

**Conclusion**

The findings of this study have shown that active teaching and learning approaches are possible in large and under-resourced classes and that they promote learner creativity which in the long process improves understanding of the scientific concepts. This works when the teacher works in collaboration with the learners in organizing teaching and learning materials including specimen, paper and markers. The teachers’ role is to facilitate and guide the process of learning by identifying the materials to be brought and ensuring that these are put to good use; and ensuring that there is discipline in the whole class and within the classroom group and creating an environment where learners listen to each other and are not afraid to make mistakes. All these are conditions for meaningful construction of knowledge as argued by constructivists, (Driver, 1989).

**References**


Exploring Effects of Argumentation Instruction Model on Science-IKS Curriculum in Teacher Education

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Abstract
The central concern of this paper is to explore the effects of an Argumentation Instructional Model (AIM) on Science-IKS curriculum in teacher education. The paper, a part of a larger study, focuses on what we call “A Reflective Diary of the Science and Indigenous Knowledge Systems Project (SIKSP)”. It is a narrative based on 19 in-service teachers’ experiences in the SIKSP using AIM. The major emphasis was to develop sets of materials and strategies to support argumentation in the classroom and assess teachers’ development with teaching argumentation. Data collected by video- and audio-recordings focused on the teachers’ attempts to implement these lessons at the beginning and end of the year. At some stage, analytical tools for evaluating the quality of argumentation were developed based on Toulmin’s Argumentation Pattern (TAP) and Ogunniyi’s Contiguity Argumentation Theory (CAT). Analysis of the data shows that although the way the teachers used AIM vary, they all demonstrated considerable expertise in their use of this mode of instruction. Further, the results indicate that the pattern of use of argumentation is teacher-specific and context dependent.

Key words: Argumentation Instructional Model, teachers’ challenges, Indigenous Knowledge Systems, Science-IKS Curriculum, Teacher Education

Introduction
The new South African curriculum policy in an attempt to make science more relevant to learners encourages teachers to integrate school science and indigenous knowledge systems (IKS) (Odora-Hoppers, 2002; Ogunniyi, 1988, 2004; Siseho & Ogunniyi, 2012). The arguments posed by this policy for science instruction cannot be over-amplified especially as most science teachers’ training leaned largely in western science (Ogunniyi & Hewson, 2008). This paper is a synopsis of what the Science and Indigenous Knowledge Project (SIKSP) has done to equip science teachers with knowledge and instructional skills to implement a science-IKS curriculum. A significant target of the research about teachers’ reflection processes refers to the design of professional development courses. During the implementation of new curricula teachers’ views enjoys meticulous interest. The way teachers treat novel approaches links to their understanding about what it means to be a teacher, how teaching should be conducted, how learning occurs, and so forth (Munby, Cunningham, & Lock, 2000; Nespor, 1987). This idea has been put forth forcefully in the following way: “When implementing a significant curricular . . . change . . . researchers argue that teachers’ belief systems can be ignored only at the innovator’s peril” (Clark & Peterson, 1986, p. 291). Indeed, this warning plays a central role in the rationale for the present study’s goal, which was to answer the following question: What are the critical argumentation abilities did teachers consider facilitating or hindering their development during their participation in the SIKS Project?

Conventionally, teaching science has intended that learners sit down in classrooms listening as teachers talk about the results of scientific investigations or the process of doing science, or following systematic directions for laboratory activities. However, this sort of passive
memorization or direction during hands-on activities is not sufficient for producing scientifically literate citizens (Rutherford & Ahlgren, 1989). Further, as stated by Osborne, Erduran, Simon, and Monk (2001), “practical work alone is inadequate to generate a bridge between observation and the ideas of science” (p. 83). They accentuate the necessity for minds-on activity such as written discourse as well as hands-on activity. Several citizens consider that disagreeing interferes with learning. They connect argumentation to an unambiguous type of hostile argument that is increasingly ubiquitous in our media culture. Tannen (1998) observed the antagonistic nature of argument that are repeatedly seen on talk shows and in the political sphere, where representatives of two opposed viewpoints shoot out talking points at each other. In these forms of argumentation, the goal is not to work together toward a common position, but simply to score points.

The learning sciences are studying a different kind of argumentation, which we call *dialogical* argumentation. For example, dialogical argumentation plays a fundamental character in science; science progresses not by the amassing of facts, but by debate and argumentation (Bell, 2004; Kuhn, 1970; Oggunniyi, 2007a; Oggunniyi & Hewson 2008). Even when two scientists disagree, they still share the universal values of science and both of them are interested in achieving the same goals. Argumentation in science is not oppositional and destructive; it is a type of dialogical conversation in which mutual parties are working collectively to resolve an issue, and in which both scientists expect to find harmony by the end of the argument (Oggunniyi & Hewson, 2008). Exposure to dialogical argumentation can help learners learn to think critically and independently about important issues and contested values. One of the argumentation models that have been frequently encountered in the current literature in science education is Toulmin’s (1958, 2003) Argumentation Pattern (TAP). Although the TAP has been useful in clarifying classroom discourse it is not free from criticisms such as: the inconsistent way in which the validity of an argument has been presented; the assumption that all arguments can be subjected only to a strictly logical forms of reasoning at the expense of equally important practical reasoning; the inconsistency in its inclusion of backings, rebuttals and qualifiers for the warrant but not the data, thus turning a simple argument into a compound one; the assumption that amassing bits and pieces of evidence is sufficient grounds for a given claim; etc (Siseho & Oggunniyi 2011; Van Eemeren et al., 1996). However, despite these weaknesses the TAP has provided some useful hints about how to assess arguments in a given context. A number of studies have simplified the structure of the TAP to make it more applicable to the field of science education (e.g. Erduran, Osborne, & Simon, 2004; Osborne et al., 2004; Simon et al., 2006). These studies have done this by classifying classroom discourses in terms of the complexity of the arguments involved such as: non-oppositional; arguments with claims or counterclaims with grounds but no rebuttals; arguments with claim or counterclaim with grounds but only single rebuttal arguments with multiple rebuttals challenging the claim but no rebuttal; etc (Siseho & Oggunniyi, 2010).

**Purpose of the study**

The purpose of the study therefore was to examine possible impact of argumentation-based activities on teachers’ ability to implement a science-IKS curriculum; run workshops for teachers on how to use argumentation as an instructional tool in classroom discourses. The argumentation framework used is based on a modified Toulmin’s (1958) Argumentation Pattern (TAP) as espoused by Erduran et al., (2004) and the Contiguity Argumentation Theory (CAT) as advocated by Oggunniyi (1997, 2007a). More details about these
argumentation framework have been published elsewhere (e.g. Ogunniyi, 2007a) and will not be repeated here. According to Hargreaves:

The teacher is the ultimate key to educational change and school improvement. The restructuring of schools, the composition of national and provincial curricula, and the development of benchmark assessments—all these things are of little value if they do not take the teacher into account (Hargreaves, 1992, p. ix).

It is not enough to acknowledge that teachers play a critical role. We need to know what their role is in order to help support teachers in the difficult task of creating an argumentative-oriented classroom. Teachers have difficulty helping learners with scientific inquiry practices such as asking thoughtful questions, designing experiments, and drawing conclusions from data (Marx, Blumenfeld, Krajcik, & Soloway, 1997). Many science teachers may not have the appropriate expertise to create an argumentative-oriented learning environment or argumentative discourse (Krajcik, Mamlok, & Hug, 2001). Teachers need to learn new ways of teaching to promote scientific inquiry, which may differ from their own earlier socialization into school science as learners (Lee, 2004; Metz, 2000). This study is aimed at eliciting teacher views on teaching, their sources of motivation and the conceptual frames out of which they conduct their work.

Method
The study involved 19 science teachers exposed to a series of bi-weekly three-hour workshops and argumentation-based activities underpinned by the TAP and CAT for a period of six months. The teachers were confronted with tasks to brainstorm individually, in pairs and in smaller groups and design a lesson and then present to the whole class group. The teachers were assigned selected readings based on the works of scholars. The purpose of additional reading assignments was to create the teachers’ awareness about how scientists go about constructing knowledge in their various fields and to show teachers how to reflect the same thing in their classrooms (Siseho & Ogunniyi, 2011). The first one and half hour block was in form of a lecture on socio-scientific topic such as environmental pollution, genetically modified food, energy conservation, the building of atomic power station at the west coast of Western Cape province, etc. They were also introduced to the controversies that ensued among early natural philosophers and scientists from the 20th century to the present period with respect to the nature of the atom, etc. Each training session included a 90-minutes workshop based on the SIKS workshop agenda where teacher training included some recommendations for encouraging learners’ use of evidence or grounds to support their claims, counter-claims or rebuttals as well as the video exemplars of good practice illustrated in the SIKS video (Siseho & Ogunniyi, 2010). Teachers were further familiarized with Toulmin’s Argument Pattern, (TAP) of 1958 (Toulmin, 2003) which is subsequently used to identify the structure of arguments manifested throughout each lesson. The SIKS Project generated the diagram below to illustrate the trajectory.
Subsequent to the preparation sessions, the teachers were given one week to organize an argumentation lesson around a science topic that would agree with the regular school curriculum, in this case following the Curriculum and Assessment Policy Statement for Natural Sciences (CAPS). During the planning phase, teachers were expected to use the feedback and suggestions from their lecturer to come up with a lesson plan that used major components of an argumentation lesson. During the three weeks that followed the planning phase, teachers implemented their lesson plans in actual classrooms.

The next one hour was used for group presentation followed by the whole class discussion and summary. The last 30 minutes of the three-hour block was used to identify the levels of arguments used by the pre-service teachers. To reinforce their argumentation skills, the teachers were then given some assignment for the next workshop. All the ABA sessions were recorded using both audio-video tapes. The transcribed materials were then analyzed in terms of the modified TAP’s levels of argument as suggested by Simon et al., (2006). Since a detail of the argumentation-based instruction used in the study has already been published, (Siseho & Ogunniyi, 2010, 2011) it will not be repeated here. The classification of the teachers levels of argument e.g. as 1, 2, or 3…, etc were carried by two independent team members. Their scores were then correlated using Spearman Rank Difference formula. The correlation stood at 0.94. This indicates a high correlation agreement between the two. It suggests a strong face, content and constructs validity of their classification.

**Findings**

Since the study involved several activities, only one will be presented here as an example of the challenges faced by teachers in using argumentation as an instructional approach in their classrooms. The result presented here is based on an item which required teachers to reflect on their experiences on the SIKSP Argumentation Instructional Model about factors they considered to facilitate or hinder participation in argumentation. The following were the findings from the study, which for convenience have been classified into three groups as follows:

Factors involving teachers (knowledge, characteristics and classroom activities)

Factors involving learners, and the learning environment

Factors involving the curriculum and available resources
Table 1: No of Factors considered facilitating or hindering participation in argumentation

<table>
<thead>
<tr>
<th></th>
<th>Teacher factors</th>
<th>Learner/Environmental factors</th>
<th>Curriculum/resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilitate</td>
<td>17 (89.5%)</td>
<td>9 (47.4%)</td>
<td>3 (15.8%)</td>
</tr>
<tr>
<td>Hinder</td>
<td>17 (89.5%)</td>
<td>7 (36.8%)</td>
<td>12 (63.2%)</td>
</tr>
<tr>
<td>Total</td>
<td>34</td>
<td>18</td>
<td>15</td>
</tr>
</tbody>
</table>

Source: Reflective diary data, for illustration purposes only

The findings indicate that the teacher factors are perceived by the teachers to largely determine both success and failure of argumentation in the science classroom. On the other hand, curriculum and resources do not greatly influence the success, but do greatly hinder the implantation of argumentation in the science class; while the learners and the learning environment moderately affect the success and failure of argumentation. In other word, the teacher can mar or make an innovative instructional method such as AIM used in this study.

Teacher factors most mentioned as relevant for participation in argumentation included the following: A sound content knowledge of the topic; A sound knowledge of the structure and use of the argumentation framework (the TAP and CAT); taking time to carefully plan the argumentation lesson and activities; practical knowledge of how to model and facilitate argumentation lessons; teaching the learners the structure and elements of a good argument and the practical usefulness of argumentation in life; encouraging learners to get involved in argumentation by listening patiently, asking leading questions, and so on; an unbiased worldview of science and IK; good listening skills; valuing each learner’s ideas and teaching the learners to do the same; avoiding to yield to the pressure of time by imposing one’s opinion on learners or stopping the learners when they are engaged in exciting arguments.

The factors that were mentioned in relation to the learners were: an advanced knowledge of the content of the topic by the learners, a knowledge of the argumentation framework used (that is the CAT and TAP); Training in group skills such as good listening and respect for the views of others; and adherence to ground rules. As far as the curriculum and learning resources are concerned, the teachers mentioned that material resources and time were important in successfully implementing argumentation in the science classroom.

Teacher factors again were considered as the most determinant in hindering argumentation. Teacher-related factors that could hinder argumentation as mentioned by the teachers were: Lack of adequate knowledge of the content of the topic; lack of an adequate knowledge of the structure, elements and practical use of the argumentation framework (the TAP and CAT); lack of knowledge of good techniques of scaffolding arguments in the science classroom; a bias towards the science worldview to the detriment of IK or the lack the proper knowledge of both the nature of science and of IK; lack of the necessary skills to model and facilitate argumentation; a high resistance to change from present practices; teachers who are exam focused.

Discussion

Teachers’ content knowledge and knowledge of both the structure and process of a suitable argumentation framework were considered by the participating teachers as very crucial for successful participation in argumentation. This corroborates the views of many science
educators (e.g. Von Aufschnaiter, Erduran, Osborne, & Simon, 2008; Osborne et al., 2004; Sandoval & Millwood, 2005). The mastery of science content knowledge by the teacher is very critical in structuring tasks for argumentation activities that necessarily include multiple competing claims from which learners need to choose, based on supporting evidence (Osborne et al., 2004). A teacher with a good content knowledge of the subject will be better placed to creatively design argumentation activities that would promote argumentation in the science classroom as Supovitz and Turner (2000) have suggested:

Content preparation was by far the most powerful individual teacher factor included in the models. Regardless of the extent of their professional development, there was four-tenths of a standard deviation difference in practice between teachers with one standard deviation below average content preparation and teachers with one standard deviation above average content preparation (p. 976).

Without a good knowledge of the topic, the teacher may not be able to structure the argumentation tasks in such a way that it will enable the learners to critically decide why one claim is better than the others. As far as the teaching of argumentation framework is concerned, many science educators believe that argumentation does not come naturally (Kuhn, 1993; Osborne et al., 2004) and therefore needs to be taught. However, there is no consensus on how this can best be done. While many science educators (e.g. Osborne et al., 2004; Simon et al., 2006; Simon, 2008) believe that argumentation should be explicitly taught, others (Kuhn, 2010) believe that argumentation is best taught through more subtle ways; for example, by beginning with familiar, everyday social issues. In this regard, Cavagnetto (2010) has identified three ways by which argumentation is generally taught to learners. In the first method, the teacher teaches learners the argumentation framework (e.g. the TAP) which they then apply across different contexts. In the second method, argumentation is used as an integrated component of student investigations; while the third approach uses controversial socio-scientific issues to contextualize and promote argumentation by asking learners to argue in support or against contentious issues such as genetically modified foods. Whatever the method employed, the teacher plays a crucial role by introducing arguments, managing small group discussions, scaffolding argumentation, modeling and evaluating arguments and making necessary interventions to ensure good quality arguments (Osborne, 2007; Osborne et al., 2004; Simon et al., 2006).

The learning context of the science classroom is shaped by the teacher and the learners together (Maskiewicz & Winters, 2012) when the teacher works to create a responsive environment (one in which one seeks to understand what another is thinking by questioning, probing and clarifying the views of others) and where each learner feels free to express his or her opinion without being intimidated. This is made possible when the argumentation starts in simple contexts, progressing to more complex contexts later (Berland & McNeil, 2010; Von Aufschnaiter et al., 2008); and both teacher and learners listen to all views patiently without just expecting only the ‘right’ answer according to what the curriculum requires (Maskiewicz & Winters, 2012). Although there are many factors that can result in worthwhile argumentation in the science classroom, several others can hinder it; most notably, a ‘perceived lack of scientific content knowledge and lack of the skills in argumentation’ (Macdonald, 2010, p. 1154) and resistance to change from teacher-centered methods to enquiry-based ones. Besides, most science teachers were taught in a Western science worldview and cannot disentangle themselves easily from the way they knew science to be since their school days. Added to this is a burden often placed on the teacher by a rigid
examination focused curriculum (Llewellyn & Rajesh, 2011; Simon et al., 2006) which makes teachers to rush without having time for any method that might take off more time. Majority of teachers in this study expressed initial apprehension about incorporating dialogical argumentation into their curricula because “the presentation of plural explanatory theories would confuse the learners or lead to the development or strengthening of a belief in scientifically incorrect idea.” These concerns seem understandable for at least two reasons. First, as Osborne, Erduran, Simon, & Monk (2001) suggest, if teachers believe that their job involves presenting carefully crafted and persuasive arguments for the scientific world-view, then presenting alternatives to the scientific explanation would, at first, seem to undermine their efforts and lead to confusion. Second, as mentioned previously, if participants in a dialogical argument believe that an explanation is evidence for a claim, then an unsubstantiated explanation can provide more support for a claim than is warranted, which might enable persuasive learners to lead others astray with unsubstantiated non-normative explanations. Science teachers have developed numerous ways to engage learners in collaborative scientific argumentation over the last decade (see Clark & Sampson 2006; DeVries, Lund & Baker, 2002; Kelly, Druker & Chen, 1998; Osborne et al. 2004; Sandoval & Reiser 2004 for examples). There are, however, a number of challenges associated with these types of activities that teachers must overcome in order to be successful that have been uncovered in this literature. These challenges can be organized around two broad themes. One theme reflects the various challenges that are associated with the nuances of learners’ scientific argumentation and the other theme stems from the additional challenges that learners face when they engage in dialogical argumentative work.

Learners encounter numerous challenges when they engage in argumentation activities that are associated with the nuances of scientific argumentation and the nature of scientific arguments (Simon et al., 2006). These challenges often stem from how the process and products diverge from the forms of argumentation they encounter in daily life rather than from a lack of skill or natural ability. For example, when learners are asked to generate an explanation for why or how something happens, learners must first make sense of the phenomenon they are studying based on the information available to them. Current research suggests that learners struggle with this process (Lawrenz, Huffman, & Gravely, 2007; Osborne, 2010; Roehrig, & Luft, 2004; Sandoval, 2003) and often rely on their personal beliefs or past experiences to do so. Another challenge that learners face when engaged in scientific argumentation is the process of generating a sufficient and useful explanation that is consistent with the types of explanations valued in science (Carey, Evans, Honda, Jay & Unger, 1989; Lawson 2004; Ohlsson 1992 & Sandoval 2003). Once learners have generated a suitable explanation, they also have difficulty justifying their explanation using appropriate evidence and reasoning from a scientific perspective. Research indicates that learners often do not use appropriate evidence, enough evidence, or attempt to justify their choice or use of evidence in the arguments they produce (Bell & Linn 2000; Erduran et al., 2004; Jiménez-Alexandre, Rodríguez & Duschl, 2000; Kuhn & Reiser 2005; Sadler 2004; Sandoval 2003). Finally, learners often do not evaluate the validity or acceptability of an explanation for a given phenomenon in an appropriate manner.

Given the dilemmas of evaluating teachers (a) impartially, (b) consistently, and (c) with regard for acquired skills, knowledge, and attitudes, SIKS Project sought to design an instrument accounting for these problems satisfactorily. The result was the SIKS Lesson Observation instrument (not included in this paper) which used detailed descriptions of 10 general areas of teacher behaviors. The ten areas (preparation for instruction, knowledge of
the subject matter, knowledge and understanding of learners, effective use of teaching skills, effectiveness of teacher evaluation of learners, effectiveness of teacher self-evaluation, teacher's ability to make decisions, human relationships and overall effectiveness of pedagogy) were chosen based on their consistent appearance in the literature on generic methods of teaching. These areas were also viewed as encompassing skills that the SIKS Project considered appropriate and crucial for the phase of their candidates on-going program of teacher education. In addition, the SIKS Lesson Observation instrument adopted for this study focused on the TAP and CAT instructional practice. Thus, the areas became the major components of the teacher preparation program at UWC. The Likert-type scale employed allowed facilitators some latitude in their evaluation of the teachers, and the space for comments directed them to elaborate on the markings they had made. As a result, the teachers could readily see specific areas of strengths and weaknesses as observed by the evaluators.

Descriptive data analysis revealed that teachers’ confidence level with argumentation teaching methods, classroom management, and science content increased with the number of science content courses taken. As teachers’ content knowledge increases, they become more confident with pedagogical issues (Shulman, 1986). Shulman argued that, when teachers know their subject matter very well, they could apply the necessary pedagogical approaches to increase learners’ understanding. In other words, this study suggests that knowing something for oneself and being able to enable others to know it are important aspects of learning and teaching. This study provides additional evidence that shows the importance of science content knowledge for future teachers to increase their beliefs about implementation of argumentation teaching method and classroom management strategies complementary to that method. However, at this point, it would be necessary to indicate the contradictory findings in the literature but because of space that will be reserved for the future publication.

Conclusion
Our effort on teachers’ research in the teaching and learning of argumentation has provided us with a conceptual and instructional tool for training teachers to promote and support argumentation in the science classroom. However, the coordination of current curricular goals with new strategies such as argumentation places extra demands on teachers. If the curriculum emphasizes content outcomes, it will be very difficult for science teachers to open up the discussion space in their classrooms to allow argumentation to take place (Sampson & Clark, 2008). Furthermore, without a shift in what is assessed in terms of teaching and learning performances, it is unlikely that some of the encouraging results observed in our research could be sustainable in the long term. However, even the short-term training of pre-service teachers resulted in attainment of intended pedagogical and learning goals, an encouraging outcome indeed.

Currently, many learners feel argumentation is a waste of time; they simply want their teachers to give them the answers. Piaget and Garcia (1991) argued that learners must be allowed to discover as much as possible on their own, and that each decision that the teacher makes for them deprives them of a potentially more powerful learning experience (Simon et al., 2006). The million-dollar question is who should bridge that gap: the teacher or the learner. If argumentation in learning situations can be isolated in some way from competition, losing face and empty rhetoric so that the focus is on understanding, explanation and reasoning, and interpersonal success, is the rule rather than the exception, the virtual promises of arguing to learn may become reality. In that case, learners do not want answers anymore;
they want to argue for them: because then they will experience autonomy, and powerful learning.

Implications for future studies in teacher education include the need to trace the developmental stages in the learning to teach argumentation - from novice to expert. What are the learning trajectories for science pre-service teachers in getting to know how to teach argumentation? This area of research in argumentation remains relatively uncharted (e.g. Erduran, 2006; Simon et al., 2006). The nature of the contribution of argumentation studies to other aspects of science teaching is equally unknown. It will be imperative to situate argumentation in other aspects of science teaching if argumentation is to have systemic validity in professional development. It is when we, as teacher educators, figure out how we can help pre-service teachers in their mediation of disagreement with reason that argumentation studies will truly extend the historical precedence of argument embodied for centuries in Plato and Aristotle.

References


Mapping sustainability and science education

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Abstract
The aim of this paper is to consider opportunities for science education and sustainability as pedagogic practice. To do this some key characteristics of recent science education are discussed as well as developments in sustainability and sustainability education. An overview of science and sustainability in the curriculum is followed by a brief discussion of approaches to learning. Finally two dimensions, science for experts vs. science for all, and sustainability as principle vs. tactic are identified and mapped against each other giving rise to four ways in which science can contribute to sustainability as pedagogic practice. They are science and technology education, education for sustainable development, sustainability science education and sustainable education.

Introduction
This paper addresses the research question:
What opportunities are there for science education and sustainability as pedagogic practice? Pedagogic practice is the pedagogy embodied in a particular setting influenced by the curriculum, the learner, the teacher, their roles, assessment and the institution. It could be formal or informal, but the focus here is on the formal, on what might occur in a formal setting in schools and universities.

In Nelson Mandela’s book Conversations with myself there is a discussion about non-violence and ANC policy, and Mr Mandela talks about the difference between adopting non-violence as a principle or as a tactic (Mandela, 2010). Recently I have returned to this text, not least in discussion with a philosopher with whom I sometimes work, one of our common interests being ‘sustainability’ in our society. Underlying this paper is a wish to understand what it might mean for science and science education if sustainability is a tactic to be adopted now and then, when opportunities arise in educational topics or settings, or whether it can be a principle that underlies planning and provision of education and the development of individuals and institutions. This is a complex issue.

Science education has a long and varied history with what Millar (2007) calls the ‘dual mandate’ of teaching science to all while preparing some for further studies. Socio-cultural and socio-scientific influences on contemporary science education include issues arising from learning, science studies and cultural diversity and more recently, sustainability science (van Eijck & Roth, 2007, Tytler, 2012). Science studies challenge Western notions of objectivity and suggest that science be considered through the ‘lens of culture’ (Carter, 2008). Cultural diversity (Carter, 2008) and indigenous knowledge (Glasson, Mhango, Phiri, & Lanier, 2010) also challenge Western approaches to science education with Glasson et al. making the case for a ‘third space’ between Western and indigenous knowledge. Gough (2008) has attempted a reconstruction of science and environmental education based on the Australian experience and the development of futures thinking has been the subject of research in the USA and New Zealand (Harkins & Moravec, 2011, Jones et al., 2012). To what extent is mainstream science education considering these issues?

The research question is also important in that science, education and sustainability are all considered as critical areas, promoted by policy-makers as key determinants of mankind’s future and the natural world. The question is addressed by looking backwards and then
Looking backwards

Developments in science education before 2000

The last half of the 20th century was characterised by several decades of reform in science education. Across the Western world new science curricula were introduced regularly, as for example in the 1995 thematic edition of the journal Studies in Science Education (1995). National committees were being asked to decide what should be taught, why and how. Concepts and/or processes were promoted, often guided more by policy makers and scientists than the findings of educational research. By the mid 1960s the ‘black box’ approach to research on curriculum innovation with its focus on outcomes (achievement and attitudes) was being supplemented by classroom studies in order to better understand teaching and learning processes. In turn by the late 1970s there was raised concern about levels of student understanding leading to research on alternative concepts and frameworks (Driver, 1981) as well as to socio-cultural explanations for science learning (Hewson & Hewson, 1988) and use of the constructivist approach (Hodson & Hodson, 1998). In recent years activism in teaching and learning has been promoted in research on science education by Roth (2009, 2010). Major comparative studies carried out from the 1950s onwards (Walker, 1976, Postlethwaite & Wiley, 1992) added a competitive edge to science education (OECD, n.d.). These highlighted the general belief that the strength of the economy and levels of innovation were linked to ‘scientific literacy’ as defined by OECD (2006). The OECD PISA studies which originated in the late 1990s focussed on science in 2006 and will do so again in 2015. The millennium proved to be a catalyst for discussions on the future. A key document in the UK called Beyond 2000: Science education for the future (Miller & Osborne, 1998) identified problems in science education which included the conclusion that the current curriculum still presented science as an objective body of knowledge and lacked a well-articulated set of aims. The problem with policy-making was described well by Hurd (2000, p. 282-288), writing from the USA:

What has not emerged [over the past quarter of a century] are policies essential for guiding decisions about the place of science and technology in human affairs and policies that represent the integrative personal-social and social-civic aspects of today’s science. Though
more than 1,000 science directives and standards have been identified, they are for the most part discipline bound.

At the turn of the century, despite curriculum reforms, science education was largely linked to a disciplinary approach based on the understanding of key concepts and scientific processes. With this backdrop in mind I turn now to a short discussion on sustainability.

**Sustainable development**

In its early years in the 1970s and 1980s sustainability was generally talked about as ‘sustainable development’ and in international aid agency work in the 1990s, this term was often used (personal experience in Malawi). The western world was worried about hunger, health, and access to and management of natural resources, especially in the developing world. The role of the UN and UNESCO turned out to be pivotal in extending the discourse of sustainability beyond poverty and resources. Several strategies have been effective. One was *Agenda 21* discussed in Rio at the United Nations Conference on Environment and Development (1992). This called for the development of action plans at national, regional and local level, and cooperation on social, environmental and health issues. Secondly, the landmark report *Learning: the treasure within* appeared in 1996 (Delors, 1998) was published by UNESCO. Four learning pillars were identified and a fifth was later added: learning to do, learning to know, learning to be, learning to live together; and then, learning to transform oneself and society, which was a response to the call for sustainability.

A third important strategy was the declaration by the United Nations in 2002 that the period 2005-2014 would be the Decade of Education for Sustainable Development (DESD) and activities would be led by UNESCO (n.d.).

Originally the concept ‘sustainable development’ was primarily linked to initiatives affecting the economy, society and the use of environmental resources, and the relationships among these areas. There were differences of opinion in whether the core issue in sustaining and improving the quality of life was the strength of the economy or the well-being of society. A nested model emerged called the radical approach (Huckle, 2006) (Figure 2a). Another model (Figure 2b) resolved the issue of the core components in the model by combining society and the economy into one issue ‘human activity and well-being’ (Hopwood, Mellor, & O’Brien, 2005). Human activity and well-being is aligned with conceptions of the ‘good life’ (Muraca, 2012).

The ‘good life’ model is deceptively simple (Figure 2b). Educational and research activities can occur where the ‘good life’ and environment challenge one another, at the boundary or some distance from it. These locations are not always known at the outset. It has been suggested that sustainability deals with “wicked problems” (Rittel & Webber, 1976). It is hard to define a ‘wicked’ problem, there is no one solution, each problem is unique, the solution is neither right nor wrong and sometimes the problem itself does not appear until the solution is found (Ferkany & Whyte, 2011). What is crucial in a ‘wicked’ problem is to acknowledge the strong and reciprocal relationship between nature and society.
The ‘wickedness’ of sustainability extends into policy and decision-making and further into curriculum development and implementation. Knowledge from different positions matters, all participants recognise the value of different types of knowledge, and participants enter a process expecting to learn something. The value of the ‘wicked’ approach lies not just in the outcome but also in the process and the ways in which participation is encouraged and developed. Current science education does not suppose ‘wickedness’ – students solve generic problems, independent of context and representing one kind of knowledge. Much of current science education, despite stated adherence to conceptual change, actually operates from the notion of knowledge building. The same could be said of education for sustainability. Students add ideas, bits of information, to their knowledge base as they move through syllabi that are largely subject-based. Sustainability thinking actually demands new concepts, challenges existing assumptions, requires conceptual change and needs systems thinking (Meadows, 2008). With this review in mind, of developments in science education and education for sustainability as we entered the 20th century, we turn now to current views of learning, aspects of sustainability science and the ‘latest’ in science education. My point is to see where science as pedagogic practice does or can contribute to sustainability.

Looking forwards
Knowledge acquisition
In recent years there have been two dominant schools of thought on the issue of knowledge acquisition: social cognitive theory and socio-cultural theory (Lee, 2010). As we work with teachers in order to understand the challenges they see in emerging curriculum areas, such as sustainability and contemporary science education, both approaches to learning might be important. Lee (2010) points out that there is a degree of reciprocity between the two traditions, knowledge building and conceptual change. As the individual learns, so does the community, and the two are inextricably related to one another. In social cognitive theory, which builds on the idea of information processing, the focus is on knowledge building, where learners accept that ideas, which are conceptual artefacts, can be improved and teachers and learners form partnerships to create a knowledge-building culture, in which there is a collective and collaborative responsibility for building knowledge. Teachers and learners need groups, partnerships and sources of information. The individual is
positioned however as separate from his or her environment but the individual and the community are equally important, with ideas being shaped and knowledge acquired by individuals in an iterative and collective way.

In a socio-cultural approach to learning, concepts are part of ever-changing frameworks, and a key to producing or acquiring knowledge is conceptual change (Lee, 2010), which can vary from weak restructuring to fundamental paradigmatic change. In the school context, learner understanding might be minor modifications. Meaning must be negotiated, leading to reification of what is being examined and for teacher groups, this affects identity and thus efficacy beliefs. Participation is essential for learning.

There is a degree of reciprocity between the two traditions, knowledge building and conceptual change as Lee (2010) points out. In order to understand the challenges in emerging curriculum areas, such as sustainability, both of the above approaches to learning and science education will be important. The community, as well as the individual, has a responsibility and a role in knowledge building and conceptual change. The difference is that knowledge building is generally an incremental process, with new bits being accumulated on top of existing knowledge which is not open to question, while conceptual change may be more radical as concepts change frameworks which in turn shape concepts.

**Sustainability science – an emerging science**

Sustainability is emerging as a ‘knowledge discourse’ in that several journals and professional societies have been established over the last 10-20 years. The interdisciplinary nature of sustainability science is reflected in publication patterns in that papers in the social science and economics journals dedicated to sustainability science appear to cross-reference each other, thus reducing impact and being outpaced by mainstream science (Schoolman, et al., 2012). Academic institutions at present are built on disciplinary models. Environmental sciences establish fewer connections with other subjects than economics or the social sciences. Finally Schoolman et al. point out that sustainability journals are actually decreasing in prestige and the general unwillingness of environmental sciences to become interdisciplinary plays a part in this. Indeed Kajikawa (2008, p. 216) maintains that it is ‘the interdisciplinary character of the research [that] hampers us in grasping the entire structure of sustainability science. Some would categorise it as an applied science, others that it is user-inspired (Kajikawa, 2008). In 2009 a special edition of the journal *Sustainability Science* appeared, then in its fourth year of publication (Steinfeld & Mino, 2009):

‘Sustainability Science’ is an emerging discipline that seeks to understand the interactions within and between global, social, and human systems, the complex mechanisms that lead to the degradation of these systems, and the concomitant risks to human well-being and security. It also seeks to provide the vision and methodology that will lead to the restoration of these systems.

A particular challenge is how to transform the educational system and process to make this possible.

Sustainability science is different from other fields of science in that it is not being carried out at highly-ranked universities and is being carried out in a wider range of institutions than traditional research (Kates, 2011). In the search for ways to work in sustainability science that reflect its complicated character, a group of scientists in Sweden put together a three-dimensional model by which one can plan and implement research on challenges of sustainability in keeping with sustainability principles (Jerneck, et al., 2011):

A research topic is selected from one of the challenges of sustainability.
The research topic is contextualised by looking at sustainability goals through the notion of justice, by considering the exploitation of technology and by predicting present and future needs. Pathways to sustainability are identified in a process characterised by participation and collective responsibility. The research must be addressed both by problem-solving empirical research but also by critical/theoretical research, working with the problem ‘as you find it’ but also requiring researchers to understand ‘how it came about’.

One of the key principles of sustainability is participation and collaboration in democratic deliberation. Participants need to learn and exhibit ‘participatory virtues’, which can be grouped into three categories: inclusiveness; engagement; and epistemic productivity (Thompson & Whyte, 2011).

Inclusiveness refers not only to representation but also acceptance of different forms of knowledge and their value for working on the problem.

Engagement requires active commitment to the task and its purpose, i.e., token representation is not encouraged.

Epistemic productivity refers not to the knowledge itself but the ability of the group and the viability of the process in actually producing knowledge and calls for participants to be sincere, pay attention, be reasonable, show humility and empathy and to be charitable.

A ‘horizon’ scan has been carried out on environmental science in South Africa (Shackleton, et al., 2011), one of the conclusions being that graduates need to become adept at working with multi- and inter-disciplinary science as most of the challenges are not ‘uni-disciplinary’. Graduates also need to be exposed to tools that deal with complexity and uncertainty and restoration science will need attention. Fields of important integrative work are: sustainability science, resilience science, social learning, environmental justice and governance, environmental economics and environmental modelling and scenario development. This horizon scan is an example of how sustainability needs to be addressed in higher education and research as well as in general education.

Science in the curriculum since 2000
The noted educator Hurd (2000) called for a ‘lived curriculum’ as the 21st century began:
A lived curriculum is designed to engage students, both alone and as a team member, in making decisions, forming judgments, and choosing actions that involve elements of risk, uncertainty, values and ethics. Problems of life and living embedded in science and technology typically overlap the social sciences and humanities. …
Some examples of core themes reflected in the new practices of science are those of health and wellness, stabilizing the global environment, new energy resources, the quality of life, and the world of work.

Hurd’s examples of core themes and the introduction of ideas of risk and uncertainty could have been a start to working with sustainability in science education. But core disciplinary ideas remain entrenched as we see some eight years later when eminent science educators mainly from the UK prepared a document Principles and big ideas in science education listing ten ‘ideas of science’ and four ‘ideas about science’ (Figure 4) (Harlen, 2010). The group stated though that the purpose of science education was ‘to enable every individual to take an informed part in decisions, and to take appropriate actions, that affect their own wellbeing and the wellbeing of society and the environment’. The list of ideas borders on the conservative and linking science to society and the environment in order to explore interactions and employ other knowledge is not addressed directly.
### Ideas of science

1. All material in the Universe is made of very small particles.
2. Objects can affect other objects at a distance.
3. Changing the movement of an object requires a net force to be acting on it.
4. The total amount of energy in the Universe is always the same but energy can be transformed when things change or are made to happen.
5. The composition of the Earth and its atmosphere and the processes occurring within them shape the Earth’s surface and its climate.
6. The solar system is a very small part of one of millions of galaxies in the Universe.
7. Organisms are organised on a cellular basis.
8. Organisms require a supply of energy and materials for which they are often dependent on or in competition with other organisms.
9. Genetic information is passed down from one generation of organisms to another.
10. The diversity of organisms, living and extinct, is the result of evolution.

### Ideas about science

11. Science assumes that for every effect there is one or more causes.
12. Scientific explanations, theories and models are those that best fit the facts known at a particular time.
13. The knowledge produced by science is used in some technologies to create products to serve human ends.
14. Applications of science often have ethical, social, economic and political implications.

**Figure 4** Ideas of science and about science (Harlen, 2010)

The ‘dual mandate’ of science education thus moves on relentlessly with key societal issues largely ignored by science educators, but are taken up in other initiatives. Environmental education has strengthened its position since the 1970s but is also sometimes at odds with sustainability (Bonnett, 2007, Chapman, 2011). Technology education has been adopted and researched in several countries, including New Zealand (Jones, 2006), and technology and creativity are being conceptualised as part of the paradigm of sustainable development (Pavlova, 2009; Stables, 2009). Initiatives such as enterprise education or innovation education have made some progress (Jones & Iredale, 2010, Jónsdóttir, 2008). Important issues have become the focus of projects and programmes on issues such as literacy, social justice, citizenship education, diversity, inclusion, multiculturalism and civics across many countries.

In the US a key steering document *A framework for K-12 science education* was released in 2011 by the National Research Council, followed a year later by a reader’s guide prepared by the National Science Teachers’ Association (NSTA) (Pratt, 2012). The framework suggests six curriculum areas for science: scientific and engineering practices, crosscutting concepts and four sets of disciplinary core ideas, the traditional trio of physical, life and earth sciences as well as in engineering, technology and applications of science.

The NSTA disciplinary core ideas could have some relevance for sustainability science, but for now the closest match with sustainability ideas is to be found in the section on *crosscutting concepts* which are listed as follows (Pratt, 2012):
Patterns
Cause and effect
Scale, proportion and quantity
Systems
Energy and matter
Structure and function
Stability and change.

A discussion by Duschl (2012) explains how learners can work with these concepts and develop an understanding of them.

Other initiatives consider science education in relation to 21st century skills. Some arguments for science education refer to the need for a competitive workforce in the face of economic competition (Bybee & Fuchs, 2006). A major seminar of educators and representatives from the economic sector in the US focussed on the intersection of science education and five selected skills:
Adaptability
Complex communication/social skills
Non-routine problem solving
Self-development/self-management
Systems thinking.

A full report is available from the National Academies Press in the US (Hilton, 2010).

It is noteworthy that these major initiatives in the US and UK remain located in the disciplinary core and do not address directly any of the conundrums being raised in sustainability science or sustainability education. The discussions in the National Academies report (Hilton, 2010) do though refer to some skills and approaches common to science and sustainability, such as *systems thinking*, *adaptability*, *non-routine problem solving* and *investigating the world through science and technology*. Any deep relationships and interactions with society and the environment are more or less missing. The emphasis on self-direction and self-management, while valuable in itself, does not reflect the kind of collective action and responsibility that might be developed in sustainable education.

Instead it is from an institute concerned with future studies and operating outside formal education that themes for science education likely to emerge by 2050 have been identified (Townsend, 2009). They include:

Mathematical world
Intentional biology
The extended self
Science in place
Transdisciplinarity.

*Mathematical world* is about the ability to discern patterns or make sense of the mass of data that will characterise the coming decades. *Intentional biology* involves nanotechnology, genetics, synthetic biology and personalised medicine, and *the extended self* refers to ways in which people will be able to extend their own capabilities though ethical issues will have to be resolved in these areas of intentional biology and self.

The experts suggested that the nexus of science will change from centralized laboratories to more lightweight innovation spots, using the social world and co-working. The *place of science* will be affected by disciplinary issues since the nature of the innovations are such that they are at the boundaries of their disciplines and of scientific institutions. Education should
aim at supporting citizens and researchers that understand and can work with more than one discipline, so that they can develop concepts and processes that are transdisciplinary. The question being explored in this paper is whether these new trends in science education and the emerging area of sustainability science can make a contribution to pedagogic practice in formal settings. There are some tantalising ideas emerging with regard to science and science education: how do they fit with ideas of sustainability now being found in the curriculum?

**Sustainability in the curriculum since 2000**

School level education in sustainability received a boost with the DESD 2005-2014 mentioned above and the work being done by UNESCO (n.d.) in developing a rich web-site of topics, issues and teaching activities in *education for sustainable development*. Topics or challenges include:
Biodiversity
Climate change
Cultural diversity
Indigenous knowledge
Disaster risk reduction
Poverty reduction
Gender equality
Health promotion
Sustainable lifestyles
Peace and human security
Water
Sustainable urbanisation

The UNESCO topics can be linked with applications of science and technology in society. The guidelines emphasise that the science needed in ESD is both from the natural sciences and the social sciences. The UNESCO (n.d.) guidelines shy away though from the ‘wicked’ nature of problems in sustainability addressed by proponents of environmental planning and education (Thompson & Whyte, 2011). The problematic nature on integration is not always addressed (Kysilka, 1998; Venville, Wallace, Rennie, & Malone, 2002).

Sustainability is generally put forward as a theme or cross-curricular issue. In Scotland sustainable development education is one of six themes across learning (Education Scotland, 2012) and it is linked to four elements: ecological, economical, social and cultural sustainability and a bank of resources has been developed to support teachers.

In Australia, sustainability is put forward as one of three cross-curricular areas in the school curriculum (Australian Curriculum, n.d.) and organising ideas are presented under the headings: systems; world views; and futures. Scholars suggest however that sustainability is ‘unconvincing’ in the Australian curriculum and is not visible in the national standards (Kennelly, Taylor, & Serow, 2011). There is also a danger that Western schooling, discourses of childhood and avoidance of controversial issues can limit the uptake of sustainability in schools, according to research in Tasmania (Johnston, 2012).

In Iceland, sustainability was included in the national curriculum in 2011 as one of six ‘fundamental concerns’, the others being: literacy, health and welfare, creative work, democracy and human rights, and equal rights (MES, 2011). All six concerns are to be woven into the subject curricula. In research preceding the 2011 curriculum a ‘curriculum key’ was developed for analysis of earlier curricula (Jóhannesson, et al., 2011). Items in the key were taken to be indicative of educational action for sustainable development. The items included: indications of values, opinions and feelings about nature and the environment; identification of knowledge contributing to a sensible use of nature; statements about welfare and public health; indications of democracy, participation and action competence; recognition of equality and multicultural issues; indications of awareness and understanding of global issues; and references to economic development and future prospects. Teachers have been able to use the key to identify elements of existing practice that could be a starting point for more work on sustainability. The key however does not capture the integrative potential of sustainability and science.

The Manitoba provincial government has actively supported education for sustainability (Efs) undertaking several initiatives simultaneously, including the funding of programs, assessment of the extent to which sustainability has been integrated into the school curriculum, development of indicators for the wider environment, building policies and supporting K-12 educators, which is considered crucial to implementation (McDonald, 2006).
An issue which comes up when working with sustainability in school contexts is that of indigenous knowledge and a potential clash with scientific knowledge (Breidlid, 2009, Glasson et al., 2010, Lewthwaite, et al., 2010). In a South African professional development project supporting sustainable development biology teachers worked with the topics of evolution and biotechnology (James, Naidoo, & Benson, 2008) but it is not clear whether this involved a multidisciplinary approach as the topics were part of the Grade 12 Science Curriculum. In New Zealand significant attempts have been made to develop education for all (NZCER, n.d.) recognising cultural diversity and indigenous science.

Mapping science and sustainability
So far this review has considered developments in science education and sustainability. The guiding research question was to identify opportunities for science education to contribute to sustainability as pedagogic practice. An answer will be sought in a mapping of different possibilities through key issues in science and sustainability.

Two dimensions
In Table 1 some of the key characteristics of training experts or providing science education for all are listed, mainly on the basis of the earlier discussion in this paper and the references cited. The ‘dual mandate’ in science education has been evident since the advent of extended public education and the lengthening of compulsory education. The traditional curriculum questions of ‘what to teach, why and how’ have led to a plethora of answers. For the sake of the argument being presented here a distinction will be made between science education and researcher as the provider of scientific expertise (for the state) and science education as contributing to the general education of all citizens (for the individual) (Table 1). Despite the enduring dominance of the disciplinary approach there are some signs that science education is being given a mandate to take account of ethical, moral and epistemological issues, to develop among students a holistic understanding of the power of science and to take on a responsibility for some of the consequences of scientific and technological development. This mandate is most often implicit, not explicit. At the same time in general education there is a need to acknowledge the value of conceptual thinking and expertise when solving problems, i.e. that a range of viewpoints and knowledge from the sciences and technology is needed in many instances. All science education should engage students in a ‘lived curriculum’ in which they develop confidence and competence for action in their private and professional lives, but also learn about risk and uncertainty (Hurd, 2000).

The approach taken here has been to look at sustainability from several perspectives. Recent developments in sustainability in education and the curriculum have been considered as well as the characteristics of sustainability science. The analysis has been motivated in part by a wish to understand whether education is working with sustainability as a tactic or as a principle (Table 2).
Table 1 Different attributes of science education as pedagogic practice

<table>
<thead>
<tr>
<th>Scientific expertise/training</th>
<th>Science education for all</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disciplinary approach</td>
<td>Multi-disciplinary approach</td>
</tr>
<tr>
<td>A ‘lived curriculum’ of science in the education of future scientists</td>
<td>A holisitic approach to prepare citizens for the future</td>
</tr>
<tr>
<td>A scientist/teacher is one who has extensive knowledge or ability based on education, research, and experience</td>
<td>Integrations of skills within contexts and across content</td>
</tr>
<tr>
<td>Context free and content-bound Objective measures of performance distinguish experts from novices</td>
<td>Teacher is a mediator of knowledge</td>
</tr>
<tr>
<td>Traditional assessment School based learning</td>
<td>Alternative assessment involving learners in self-evaluation</td>
</tr>
</tbody>
</table>

Table 2 Attributes of sustainability seen as a tactic or a principle

<table>
<thead>
<tr>
<th>Sustainability as a tactic</th>
<th>Sustainability as a principle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disciplinary approach possible</td>
<td>Transdisciplinary approach necessary</td>
</tr>
<tr>
<td>There is a task with a specific mission and a specific objective</td>
<td>A code of conduct is presupposed; normative</td>
</tr>
<tr>
<td>Often involves a specific location</td>
<td>Participatory virtues</td>
</tr>
<tr>
<td>May lack overall strategy</td>
<td>It represents a set of values that orientate and rule the conduct of a concrete society</td>
</tr>
<tr>
<td>Uses opportunities May fill gaps Can create new/innovative outcomes Focus on discrete, often behavioural type of activities</td>
<td>It promotes the development of action competence and activism</td>
</tr>
<tr>
<td><a href="http://en.wikipedia.org/wiki/Tactic_(method)">http://en.wikipedia.org/wiki/Tactic_(method)</a></td>
<td>There is acceptance of a systems approach as an essential characteristic</td>
</tr>
</tbody>
</table>


The attributes of sustainability currently found in education, research and policy seem to indicate that, for some, studying or researching an issue of sustainability is at best serendipitous or at worst jumping on a bandwagon. Sustainability is used as a tactic to meet a funding requirement, to be ticked off on a list of indicators, to fill a gap in a timetable. The educator or researcher could become more fully involved in understanding sustainability as the task is carried out. The idea however that sustainability might become a principle for the way a university supports research or plans teaching is met by cries of ‘But what happened to academic freedom?’ or ‘I do ride my bike to work’. Thus it is fair to say that only a few examples of sustainability are being used as a fundamental principle in research and education. It seldom underlies selection of topics nor implementation, be it a massive centralised concern or a small rural school.

Firth (2011) has discussed the writings of Bonnett who suggests that environmental education must have two agendas: first, a short-term pragmatic agenda where science and technology...
are brought in to limit damage and to work with a global vision of sustainable development, and second, a long-term agenda where a relationship with nature would be developed and nurtured by education. The latter is ‘undermined by the dominant cultural mindset of our time’ (p. 16). Bonnett’s short-term agenda seems to promote sustainability as a tactic while it is in the long-term that sustainability can be deployed as a principle by which to act and live.

Findings and discussion
Now it is time to approach the research question. What opportunities are there for science education and sustainability as pedagogic practice? Mapping the dimensions of science education (Table 1) against attributes of sustainability (Table 2) gives rise to four forms of pedagogic practice that relate sustainability with science education (Figure 5). Each of these will be briefly discussed. First ‘science for experts’ is considered (left-half of the figure) and then ‘science for all’ (right-half).

Figure 5 Contributions of science education to sustainability
Science and technology education (upper left, Figure 5) is education as it is provided for those who wish to develop expertise and is typically found in upper secondary schools and universities and in some cases in lower secondary schools. It is a ‘school subject’ or university course, taught independently from other courses as ‘silo’ science or a single discipline, and assessed by examination. The disciplinary base is strong. There are however opportunities for such pedagogic practice to be broadened and taught more holistically in order to promote understanding of the roles of science in society. The power of this form of education is enormous, resting as it does on highly specialised vertical discourse and structures of knowledge (Bernstein, 2000) and admission to the academy is prized. It is not impossible, and is indeed desirable, for science education in this quadrant to work with sustainability, but it may be a short-term tactic rather than a long term commitment (see comment below).

Sustainability science (lower left, Figure 5) is an emerging but growing field of research and education but although it aims to develop experts, it is not necessarily found at major research universities which tend to favour mainstream science (Bettencourt & Kaur, 2011). There is a risk involved for those who wish to practice ‘sustainability science’, not so much in developing expertise which calls for multi- or even transdisciplinary approaches (Jernbeck, et al., 2011), but in having their expertise
recognised by the academic environment. There are significant opportunities for science education to adopt this approach in secondary (Sharma, 2012) and tertiary settings and in creating research fellowships and grants to open up the field, infusing scientific practice with fundamental concerns of sustainability. It is a breakaway from more the traditional and tactical approaches of science and technology education and requires a change in thinking, such as adopting a systems approach (Meadows, 2008). The practice identified in the upper right (Figure 5) and which falls under the area of ‘science for all’ is education for sustainable development (ESD) which has both power and potential, but in many cases is enacted at the tactical level, using opportunities which present themselves, but not being guided by a worldview. There may be interest in the school or university in sustainability but that is only sporadic, possibly reactive rather proactive. This pedagogic practice is not systemic as interest in ESD may be limited to only a few teachers or schools. Curriculum development around ESD is complex as policy-makers introduce sustainable themes at national level, but because of the strong subject-base of school organisation and inflexibility of structure and use of fixed time allocations, it may be an ‘add-on’ in school settings, a tactic to be ticked off on the list of indicators. Sterling (2001) says that education for something tends to become both ‘accommodated and marginalized’, it might occupy a niche ‘but the overall educational paradigm otherwise remains unchanged’ (p. 14).

This leads us to the fourth option sustainable education (lower right, Figure 5) which is pedagogic practice accessible to all forms of general or public education and which offers an opportunity, like sustainability science, to do something different. The sustainability thinker Sterling (2001) speaks of this a ‘new educational paradigm’. The real need is to change from transmissive toward transformative learning where education is built on an ecological and participatory worldview. Sustainable education, according to Sterling (p. 84-85), will be extended, connective and integrative. It will be future-oriented, relational and inclusive, to name but three attributes. It will build on conceptual change though there will also be a role for incremental knowledge building. It will be participative and will encourage epistemic productivity. Problems will be contextualised, and drawing on action competence and activism, their wicked nature will become apparent in the search for the ‘good life’.

Final thoughts
If sustainability is viewed as a tactic, perhaps to tackle problems presented or created by others, then science is considered as a driver of change and the only expectation is that science will find a solution to the current problem but not necessarily to challenge the source of the problem. Knowledge-building, an incremental approach to new knowledge, is likely to look at behavioural change as an indicator of learning. It is possible that individuals or organisations experience increased self-efficacy and continue to contribute to change in society by altering behaviour in detectable ways.

If sustainability is taken to be a principle education will require new concepts and a changed framework. Science becomes one of several tools for change, with education focussed on collective rather than individual responsibility. New knowledge derives from conceptual change. Learning will draw on activism, the active engagement of a learner in changing a situation (Roth, 2009, 2010), and action competence (Mogensen & Schnack, 2010), the ability to understand ‘why we are where we are’ and to take actions that make a difference. As Roth (2010) said: … it is not the understanding of the world that matters but its transformation.
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Conceptual, attitudinal and practical change concerning science and indigenous knowledge integration using argumentation

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Abstract
In 2004, the School of Science and Maths Education (SSME) embarked on the Practical Argumentation Course (PAC), aimed at equipping science teachers with skills for Science and Indigenous Knowledge integration (SIKI) in science classrooms. PAC provided opportunity for participants to explore the nature of Science (NOS), nature of IKS (besides the metaphysical aspect), along with dialogical argumentation (DA) and related Contiguity Argumentation Theory (CAT). The paper used a mixed methods (qualitative, with basic statistics) to report the cognitive, attitudinal, and practical change trajectories of participants who enrolled in the PAC, highlighting reasons for their initial oblivion/negativity. Their continued niggling concerns about the feasibility of implementing the curriculum mandate to integrate science and IKS were dialectically discussed. Ogunniyi’s CAT helped to locate the status of their convictions. Claims to acquisition of knowledge and skill for using argumentation as a tool for socio-culturally relevant instruction is elucidated. Catalytic factors that accelerated change are presented, in terms of CAT, together with the disclosed internal self-argumentations.

Introduction and background of the study
Globally, concerns about science teaching have been expressed by teacher educators, government departments, researchers and other stakeholders (Hewson and Ogunniyi, 2011). The low performance of learners in Maths and science and the low enrolment for science-related careers have been a worrisome issue to all education stakeholders. Fakudze (2004) asserts that this phenomenon results from the traditional presentation of science in a manner unrelated to learners’ background and lived experiences. For the NOS to become relevant and accessible to learners teachers need to conceptualise learning as embedded in socio-cultural significations (Wells, 1999). South Africa’s new democracy joined the trope of countries taking steps to amend their science curriculum to bear socio-cultural relevance to the learners. The revised National Curriculum Statement (rNCS) places much emphasis on IK in school science and the Curriculum Assessment Policy Statements (CAPS) further expatiates on unit standards and assessment. This move is welcomed by social scientists who point out that although classrooms have become culturally heterogeneous, science has continually portrayed as an esoteric body of knowledge discovered by geniuses (mostly Caucasian). Some science text books contain pictures of scientists such as, Einstein, Newton, Mendel, Galileo, Faraday and others attest to this. Such displays carry symbolic meanings that may serve to buttress that notion.

Ogunniyi (2011) stresses that progressively distancing classroom science from learners’ lived experiences subsequently alienate them to science. The development of higher mental functions is primarily mediated by culturally embedded significations, such as, artefacts, activities, and practices that carry varied meanings and serve as reference points to the learner in the learning process. Learning is mediated by a host of factors, one of which is the extent to which the cultural milieu in the classroom bears relevance to the learners’ frame of reference (Ladson-Billings, 1995). Socio-culturally relevant classroom practice is therefore
obligatory. Hence, conceptualising these mediating entities varies from learner to learner; and is not usually based on the physical appearance of that entity but psychosocially embedded in the child’s cultural essence (Vygotsky, 1978). For instance, arts, objects or artefacts; even words, such as, ‘father’/‘mother’/neighbour, school and family are culturally embedded. In South Africa, a range of learners’ experiences/activities differ by culture⁷. All of these carry particular meanings for different learners even within South Africa. Simon and Johnson (2008) contend that:

Because science education has always been more concerned with students’ understanding of scientific concepts, adopting different aims in the science classroom it is notoriously difficult. The normative practice in science is predominantly that of transmission …, the focus being on the delivery of science facts and concepts. Yet … argumentation … can provide a means of promoting a wider range of goals, including social skills, reasoning skills and the skills required to construct arguments using evidence (p. 670).

Aikenhead (2000, 2001), describing the efforts made in Canada to bridge aboriginal knowledge systems and western science, highlights the painful process of border-crossing that learners must negotiate in an attempt to derive meaning from classroom science; regardless of where they come from; rural, urban, semi-urban, informal or downtown slum areas across the nation and in the world. He posits that they must first construct their own understanding before they are able to make the cognitive shifts appropriate with the NOS (Aikenhead, 1996).

Social constructionists (Dewey, 1956, 1985), social learning theorists (Bandura, 1977, 1986), constructivists (Vygotsky, 1978), and social constructivists (Hodson and Hodson, 1998), sociocultural learning theorists (Otulaja, Cameron and Msimanga, 2011) and critical multiculturalists (Giroux & McLaren, 1989; McLaren, 2003; Kincheloe, 2004; Amosun, 2010) all agree that instruction should mandatorily give voice to learners by soliciting, “students’ conceptual understanding through dialogues” (Siry et al., 2008, p. 4), when they navigate the learning terrain. Pillay, Gokar & Kathard (2008), and Amosun (2010) found that many South African teachers still operate in the assimilatory mode and therefore require adequate preparation for the required paradigm shift for implementing a socio-culturally relevant classroom practice. The ontology and axiology, derived from their home and ethnic background, interfere with their professional practice. Many science education researchers, including Hewson and Ogguniyi (2011), Fakudze (2004), Amosun and Ogguniyi (2011), recognising the science in IKS and IKS in science proffer IKS integration with science as a means to execute a non-assimilatory, social constructivist, socio-culturally relevant form of science classroom practice.

IK’s significant contributions to global knowledge
The physical universe attests to incidents that have no plausible answers although, the NOS holds that future discoveries will unveil them. It is no secret that most of science had its precursive rudiment in IKS (Semali and Kincheloe, 1999). Warren (1991) asserts:

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⁷ The varied culture-related activities in South Africa include, soccer versus rugby, cricket and hockey; bedtime stories versus tales by moonlight; braai parties, beach picnics, visit to amusement parks, swim in home/community pools versus swimming in nearby poodles, rivers and lakes; indoor commercial toys such as card, computer, video games versus hand-made wired or wood toys and street-plays (tyre racing), roaming in fields or forests.
Indigenous knowledge (IK) is the local knowledge … that is unique to a given culture or society. IK contrasts with the international knowledge system … Significant contributions to global knowledge have originated from indigenous people, for instance in medicine and veterinary medicine with their intimate understanding of their environments. Indigenous knowledge is developed and adapted continuously to gradually changing environments and passed down from generation to generation and closely interwoven with people’s cultural values. (p. 1). Siry et al. condemn the traditional western dismissal of alternate conceptions, contending that:

What is termed misconception [by most science teachers], could instead be accepted as an alternative or ‘‘other’’ explanation of a natural or science phenomenon. Who’s conception or misconception? Is it only mainstream, Newtonian, Baconian, Cartesian understandings and explanations of science that counts? Should it be only Westernized explanations and understandings of scientific phenomena that are privileged? What about indigenous knowledge? Where is the polysemy of scientific phenomena? Shouldn’t modern science be multicultural? When teaching for conceptual change, whose goals are served? (p. 4).

The good news is that IKS has a track record of guaranteeing global sustenance and its benefits are still having far reaching and formidable practical influence on most of the earth’s masses because of its resilience (Rajasekaran, 1993).

In the backdrop of these ‘similar but different’, verdict about IKS and science, Sibisi (2004) asserts:

Indigenous knowledge[‘s] … contribution to science and technology is often underestimated or not known. …. Masai pastoralists actively immunized their herds by inoculating healthy animals with saliva froth of freshly diseased ones. … English midwives … stored molding bread with their delivery utensils and cloths. Yet, Pasteur received recognition for pioneering vaccination and Fleming for the discovery of penicillin. For centuries, local communities have relied on their [IK] … to cope with the challenges [of] harsh environments: extended droughts, flash floods, epidemic pests, or infertile soils. Farmers have developed their own systems of weather forecasting by observing cloud formations, bird migration patterns, seasonal winds …., or worked out complex, sustainable land use systems. In this sense, IK has evolved into a science and technology of its own, with farmers and communities performing as scientists and innovators—observing, drawing conclusions, and taking action (p. 34).

The major difference between IK and science is that the NOS insist on positivist empiricism as the superior and only tenable knowledge system; eschewing, debunking and relegating all others, especially IKS (Bell, 1979). IKS on the other hand simply makes assertions about what, how and when things should be done and how they should be done. It does not necessarily give reasons for the assertions.

**Argumentation for socio-cultural classroom practice**

Ogunniyi and Hewson (2008), Nhalevilo-Afonso and Ogunniyi (2011), in agreement with Toulmin (1990), Osborne, Erduran, and Simon (2004), maintain that allowing learners to engage in argumentation and critical reasoning is an effective route to the discovery of the NOS. They assert that Dialogical argumentation (DA) is a perfect tool for implementing SIKI. Amosun and Otulaja (2012), outlining benefits of DA declared that,
1) It provides opportunity to bridge socio-cultural gaps that may exist between learners and teachers
2) It encourages mutual learning through interactions.
3) It presents opportunities to listen to others’ perspectives and hopefully, get better insight into issues discussed
4) It provides opportunity for equity
5) It “catalyzes and tacitalizes change in context (because no one remains the same), enabling participants to gain enough agency (power to act) to transform their situation by themselves” (p. 4).

Knowledge, valuation and practice as evidence of change
Personal attitude ‘towards’ a concept differs from having the attitude ‘of’ that concept. This means, attitude to IK, SIKI differs from an attitude of (apposite to) SIKI; a more complex locus. It follows then that a real change in stance will involve an awareness of IK and SIKI; the development of favourable attitude to IK and SIKI; a discernible valuation and strong desire for the implementation of SIKI as mandated by the curriculum and a visible drive to authenticate IKS through inquiry. Osborne, Simon and Collins (2003) cited Klopfer’s (1971), list of six progressions that one traverses from the initial reception of an idea to the formulation of an attitude, development of value and subsequent adoption of the idea, which culminates its practical application. Osborne, Simon and Collins), referring to Klopfer’s categories, avow that acquisition of knowledge does not necessarily transpose to attitudinal/value change; neither does attitudinal change guarantee adoption, and application.

Purpose of the Study
Change in deportment necessarily results from critical encounters such as the PAC programme (Mezirow, 1995). Such encounters usually lead to the acquisition of new paradigms of thought and action. The study’s aimed at finding the effect of the argumentation programme on the participants in the PAC programme and to find out whether participants progressed from their initial acquisition of knowledge, to attitudinal change and an adoption of relevant practice (behavioural). Narratives from participants about their experiences and evolving stance (position) during and after participating in the developmental process engenders three analytical strands namely, the initial and current stances concerning IK and SIKI; as well as the personal experiences derived from the PAC. This article’s three-fold agenda is therefore to:

1) Document initial and current stances of participants about IK and about SIKI integration (as required by the curriculum)
2) Identify concerns about SIK integration process and the trajectories of self-argumentation, internal debates that arise from those concerns
3) Decipher how participants’ portray a progression in stance from awareness, to knowledge, attitudinal and values change, leading to a willingness to engage in practices contingent with the new stance.

This paper reports the narratives of nineteen participants in the PAC programme detailing their initial stance (disposition/attitude) at first contact with the PAC and introduction to IK and the SIKI mandate for science classroom, using argumentation as a tool. The paper highlights the process of change; the factors that influenced the change and the current stance and course of action taken by the participants.

Theoretical/Conceptual framework
Toulmin’s (1990) Argumentation Pattern (TAP), provides structure to argumentation by proposing a framework for discourse within which discussants having different viewpoint
systematically articulating and present their views while others listen and reflect on the assertion/claims and reasons offered for the claims (Ogunniyi and Hewson, 2008; Ogawa, 1995). Leitão (2000) cautions that the goal of argumentation is to establish the validity of claims presented through well-reasoned or well-grounded arguments. It is not to win a case, but to clarify misconceptions and reach a state of mutual cognition or possible consensus.

Contiguity argumentation theory
When distinctly different ideas come together they are likely to repel each other (Ogunniyi, 2004) first, then an internal argument or self-conversation, occurs at the micro-neuro-psychical level, as competing schemata of thoughts arise in the memory; assumed to be the most active center of consciousness (Ogunniyi, 2000), through which an individual navigates the contexts of daily encounters. This process of internal structuring, restructuring, brainstorming or intra-location is an active engagement with one’s embodied experience. It involves a series of dynamic interactions of the non-logical metaphysical, logical-empirical and rational elements of the mind (Ogunniyi, 2002, 2007a; 2007b). Faced with new concepts, a person decides whether to accept, reject, adopt or admit the new concept. During this micro-neuron decision making process, he/she attempts to seek areas of cohesion in which the ideas coalesce and form a deeper level of understanding than was previously inexist. This dynamic process of finding a meaningful state of co-existence for conflicting ideas was categorized into five cognitive stances referred to as, Contiguity Argumentation Theory (CAT), by Ogunniyi (2007a, 2007b) and described as follows:

1) **Dominant** – When an idea is overwhelming because it conforms to acceptable social norms, identity and standards. 2) **Suppressed** – When an idea is suppressed in the face of a more valid, predictive, empirically testable or dominant norm. 3) **Assimilated** – In this state, the less powerful idea capitulates or becomes sub-summed by the dominant or more adaptable one. 4) **Emergent** – At this level, a completely new knowledge emerges as the prior knowledge was never in existence or either deemed untenable. 5) **Equipollent** – At this point, two competing ideas are embraced comparably on equal cognitive level, such that they co-exist without any dissonance. Notably, there is no absolute stability within cognitive stances because individuals may shift position as dictated by their contexts. The equipollent stance does not mean that the newly acquired knowledge does not necessarily result in a significant modification of one’s worldview but a coexistence of prior and new conceptual stance.

Design and procedure
From 2004 until now (2012), the Science and Indigenous Knowledge Systems Project (SIKSP) team continue with research and teacher development for SIKSI. Participants in this study have engaged in vigorous sessions of practice in argumentation, involving documented and coherent presentation of claims, warrants, rebuttals, counter-claims, and concessions. Practical design of instructional materials and vigorous SIKS research; timed and videoed peer micro-teaching at various schools, followed by critical reviews aimed at escalating participants’ conceptual and practical skills, were vital aspects of PAC. The study explores participants’ epistemology (personal knowledge), axiological (values), ontology (effect of knowledge on attitude) and valuation of new knowledge predisposing to application (commitment to practice, dissemination and propagation). A dialectic discussion about participants’ progressions from initial to current positions is presented. This article only explores the first of six questions in the inquiry, which is, “What narratives can you tell about your experiences and evolving stance (position) on the implementation of the curriculum demand to integrate science and IK in the classroom”?

19 of the current SIKSP
members who have been exposed to the PAC programme were given six questions that engendered a reflective diary of their experience of PAC and subsequent growth. The written narratives were organised, into initial and latter stances, noting reported changes in knowledge, attitudes, and practices.

Aware of the limitation of surveys in providing the reasoning behind the responses, a three scale survey with six questions was administered in addition to the reflective diary. It generated richer data that revealed the participants’ thought processes, their progression from knowledge acquisition to attitudinal change leading to valuation and commitment to action (practice) as outlined by Klopfer. Underlying concerns about IK and SIKI were also noted. Mixed qualitative and quantitative methods with simple proportional statistics/’frequency’ diagrams are used to show participants initial and current awareness. For anonymity, pseudonyms are assigned to participants.

Findings and discussions

Participants’ initial and current stances were categorised into three attitudinal stances, negative, positive and oblivion. Table 1.1 and Graph 1.1 show the initial and latter dispositions of participants in terms positive, negative and awareness of IKS as a valid knowledge area.

Table 1.1: Participants’ initial and current stance to Indigenous knowledge (IK)

<table>
<thead>
<tr>
<th>Attitudinal position (number of participants)</th>
<th>Initial Stance (%)</th>
<th>Current Stance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positively disposed to IKS (4/19)</td>
<td>21%</td>
<td>100%</td>
</tr>
<tr>
<td>Negatively disposed to IKS (10/19)</td>
<td>53%</td>
<td>0%</td>
</tr>
<tr>
<td>Unaware /Vaguely aware of IKS (5/19)</td>
<td>26%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Graph 1.1: Participants’ initial and current stance to Indigenous knowledge (IK)

1. Do you openly portray that you hold a favourable attitude towards IK and the integration of IK with science?
2. Do you accept that science and IK integration is the best way to develop learners’ interest in science?
3. Have you adopted the attitude of always promoting the integration of science IK?
4. Do you enjoy the science integrated with IK approach to science education more than the conventional approach?
5. As a science teacher, do you find yourself having a maintained interest in IK-science related activities?
6. Have you developed interest in pursuing a career as a consultant on IK-science related instructional practice?
Five (26%) of the nineteen participants were unaware; ten out of nineteen (53%) were negatively disposed and only four (21%) were positively disposed to IK. Naturally three PAC facilitators who currently coordinate the SIK research/training project expressed positive stance from the beginning. Shaid and Onati said:

I valued the role … before modern science … became common, … the role that “herbal remedies … remedies played in communities … to treat … common ailments. (Shaid, facilitator).

I always felt that the traditional methods of food preparation, agriculture, architecture, medicinal plant use; use of certain chemicals for different purposes, e.g. minerals for softening food and purifying water, were useful in helping learners to relate science to social life and traditions.(Onati, facilitator)

When the three facilitators’ responses were exempted from the data set, a different picture emerged, revealing that eleven out of sixteen people (almost 70%) initially harboured negative stances. Combining the negative responses with those who registered naïvety, needed training for SIKI at the inception of the PAC, we can safely conclude that, excluding facilitators, sixteen out of sixteen (100%) of the participants came into PAC and SIKSP with negative notions of IK and SIKI.

Reasons given for their initial negative stances include perceptions that IK is inferior or simply untenable because it does not value testability and the view of science as the superior, ultimate form of knowledge. Perceived as witchcraft, they viewed all IK as weird, abstract and superstitious. Others neither knew about IK, nor understood it; thereby lending credence to Warren’s (1989, 1991, 1992) observation that most people hold discrepant views of IKS as a valid form of knowledge. But IKS does no simply involve metaphysical realms of operation, but they consist of processes, practices and procedures that are tangible; just as is the case for science.

Latter dispositions to IK and its integration with science
Currently, none of the participants report a negative attitude towards IK and SIKI. Graph 1.2 depicts the participants’ initial and latter notions about SIKI. All participants (100%) avow IK as a tenable body of knowledge. None was sceptical of the feasibility of linking IK and science. They remained adamant about IK’s contributions to modern science, and insist that better performance in science will result from using argumentation to link science-IKS.

Table 1.2: Participants' current stance towards science and IK integration

<table>
<thead>
<tr>
<th></th>
<th>Initial Stance (%)</th>
<th>Stance</th>
<th>Current Stance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welcomed IK integration with science (6)</td>
<td>32%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Sceptical of IK link to science (2)</td>
<td>10%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Against IK integration with science (11)</td>
<td>58%</td>
<td>0%</td>
<td></td>
</tr>
</tbody>
</table>
Providing deeper insight into factors that facilitated the change in stance, they mentioned the interactive engagement with theory and practice during the PAC, saying, it illuminated their conceptual frame of mind and empowered them to implement the argumentation method in their science classrooms. The PAC and SIKSP weekend forums enlightened them about the legitimacy of IK; thus providing the critical encounters that Mezirow’s (1995) theory avows leads to personal transformation. The following disclosures show that most participants have moved to the equipollent stage of Ogunniyi’s CAT, passionately in support of IK and science:

**Andile:** At first I didn’t have much information about this issue so I didn’t value it. In the process of interacting … rigorous sharing ideas … I have participated, and even implemented it … I strongly support … Science / IK … I value it as a viable project, whose implementation is long overdue

**Dumisani:** I never thought of any science in IK. … began reflecting on the practices of my people and saw that many of them were in fact congruent with science

**Lilian:** I thought that cultural knowledge was less important than Science … a type of witchcraft.

These workshops are so valuable to me … made me realize … how precious IKS is and how I nearly lost my valuable experience of learning IK from two cultures (black and coloured)a young age. Science deprived IKS of its value

**Noluntu:** Everything was weird because it was my first time to hear about it.

began to understand … only recently, … the values and richness in traditional practices. The exposure to argumentation has changed … ways I look at everything around me, dialogue, etc. … I am quite passionate to see this succeed…I am becoming more critical now and I can express myself better without being offensive.

It sounded foreign but interesting

**Chad:** Felt that IKS and science were two different knowledges … almost impossible to combine the two.

Science … is usually taught as a product. But … My understanding grew … modern science is … just a conglomeration of knowledges adopted from indigenous people all over the world. …. science had many shortcomings … IKS … had advantages … it focused more on the ethical and socio-scientific … not influenced by greed and
commercialization which mars the orthodox science ... This ... convinced me that there was a real need to mitigate by ... integrating the two ... to enrich our experiences of the world

Rosaline: Working with people ... from different communities has given me insight into perspectives on IK that ... questioned my western views ... taken me out of my comfort zone to explore alternative ideas..., particularly issues of a socio-cultural nature. Argumentation ...a strategy to initiate discussion and reveal ... cultural perspectives ... alternative ideas about science ... Very illuminating

Fabian: I was not so fascinated by IKS at all I have now reached a level where I am confident of integrating these two worldviews harmoniously.

Peter: From zero understanding ... to the realization that modern knowledge has as its origin in ... simple practices that were common ..."IKS" ... was a way of living ... should be today also.

Fezeka: Discovered in practical ways, how contiguity argumentation can be used in the classroom. Opened my eyes ... argumentation is the most appropriate vehicle for achieving the mandate to integrate science and IK

Self-argumentation: implementation of science and IK integration

Sixteen of the nineteen participants who wrote the reflective diary responded to a second set of survey questions. Eleven of them gave deeper insights into the cognitive states of mind (self-argumentation) experiences concerning the feasibility of propagating SIKI. Graph 1.3 shows that most participants, who changed their stance positively, still have obvious reservations/concern about possible impediment against SIKI. The fact that some of the participants who earlier reported 100% positive disposition to IK and SIKI still carried burdens concerning SIKI, This confirms Ogunniyi’s assertion that argumentation goes on in people’s minds all the time. It is therefore not surprising that 50% of participants could not categorically say that they have maintained interest in SIKI. They could neither avow that they will devote themselves to promoting SIKI nor could they claim to enjoy SIKI lessons better than traditional empirical presentation of science.

Response to the first four questions on the three scale survey meant to probe the levels of change showed that participants whose responses were, “somewhat”, are almost equal to those who said “very much”. Dumisani, for example, who was initially sceptical of IK and SIKI later, embraced the idea; but he is still bothered with the impediments to SIKI implementation. He does not see himself living to propagate it. The evidently on-going internal argumentation does not present a clear picture of his location in terms of CAT. Although he registers strong conviction about the need to integrate IK and Science, for economic reasons, he is not ready to stake his future on propagating his conviction through a related career of propagating the need for an SIKI science instruction
He said:

Dumisani: Science-IK integration can develop learners’ interest, but … the modern technology … has swept the world … the young generation. … Interest in IK is small; and many people … view IK [as] backward-looking instead of forward… I have not made up my mind to definitely pursue a career in IKS-related practice … I don’t know if it would give me an enviable place in the job market … my country is not much into [IK. They] focus … on getting western modern technology.

Others like, Donald, Eddie, and Feroza, who have come to embrace IK and SIKI registered more concerns about IK-Science. They said:

Donald: I do embrace SIKI, however … it has lots of challenges and hindrances … lack of teaching resources, an exam orientated curriculum, lack of professional development programmes.

Eddie: I firmly believe that … SIKI curriculum is the way forward, but we are still a long way to implementing …. It would mean revising the current RNC [to] put more emphasis on prior knowledge, critical thinking … rational learning …. I am 100% in favour … the curriculum isn’t … a lot needs to be done.

Feroza: Learners come … with diverse knowledge systems, … Acknowledging the[ir] IK … makes it easier for them to connect [with] science. Currently many teachers do not teach IK … they don’t know enough or anything about IK, … it’s my duty to inform my colleagues… with skills and knowledge I’ve gained … I can train and support teachers to implement SIKI.
Feroza and Prince seemed resolved to propagate SIKI, despite the concerns they disclosed, and Kingsley was anxious in an attempt to integrate SIK, the “knots and bolts of science” and the inherent NOS may be replaced by IK. He reasoned that since science drives the economy it should be preserved and not eroded:

Kingsley: IK lends itself to contextualising science, making it relevant and finding coherence with everyday knowledge. [however], IK should not ... replace the nuts and bolts of science. Science is ... what drives the economic-business-technological world. ... Acknowledgement and respect for an IKS ... would bring ... ownership and participation from indigenous peoples

Rosaline: I have an abiding interest in the IKS of South Africa’s diverse culture. ...it is vital to capture what remains of the existing cultural and medicinal practices, stories, proverbs, language nuances ... before they disappear forever as the elders [with embedded knowledge] pass... on. One ... way of capturing this knowledge is argumentation ... learners [can] feel comfortable ... and proud of the everyday cultural knowledge they bring from home. ...appreciate IK’s... contribution ... [its] parallels with ... scientific knowledge not ... a dichotomy opposed to modern science but ... different ... equally valid.

A few participants who stated that that they are devoted to SIKI show readiness to practically propagate the idea and ensure the curriculum mandate of SIKI implementation. They disclosed as follows:

Prince: “I am ... privileged to be... part of ... SIKSP ... since 2006 and realise it is in our (my) hands to enlighten other teachers.

Leticia: I am fully convinced that Sciences and IKS need to be integrated.... IK recognition [imperative]... At this stage I am now confident to teach, plan and design materials for SIKI. I am guiding and supporting my colleagues ... on how to teach, integrate and plan their lessons.

Shaid’s disclosure captures most participants’ views about what they discovered from being members of the SIKSP team and PAC course; how they conceptualize practical/empirical nature of IK that correlates with the NOS. They however, hold the view that the metaphysical aspect of IKS lies outside of science and should be a separate body of knowledge.

Shaid: In the beginning it was important to isolate the different types of IK – metaphysical [and] practical – ... looking at integrating science and IK, ... it is important to isolate IK practices which have a practical “empirical” application and compare that to the modern science application.... Although ... IK ... might seem cumbersome,... time consuming and ...science ... efficient, it ...show[s] how modern science conceptions and applications have ...indeed been based on IK conceptions, ... nature of science processes ...building on the known, and ... progressing ... into what we today understand as ...modern science conception.

Many of the participants disclosed aspects of the PAC which they reasoned to be catalytic in bringing about change in disposition to IK and SIKI, and facilitated the acquisition of skills for utilising argumentation as a tool for SIKI in the class. Leticia said, “demonstration lessons ...and feedback ... given by the other members and ... materials ... developed at the workshops ... gave better understanding on how to design materials/activities for the learners”.

358
Participants in this study are all education practitioners and are positioned to present the views of learners and teachers among whom they practice their profession. All the participants started off in the PAC course either ignorant or opposed to one or both IK and SIKI. Although a hundred per-cent changes in stance was noted, further probe using a three-scale, six-point, survey instrument, provoked more disclosures from participants’ about gnawing concerns over the feasibility of convincing teachers and learners to adopt argumentation as a socio-culturally relevant method for SIKI.

Conclusion
The context in which participating teachers are embedded largely influences what is conceived; hence, their report about science education is embedded in the reality of their experiences, both at schools and within the PAC and SIKSP. In agreement with Giroux and McLaren (1989), the study shows that a transformation in teachers’ practice is possible Membership of the PAC programme and SIKSP bi-monthly Friday and Saturday seminars/workshops predisposed them to change. They acquired practical skills necessary for SIKI in science classrooms using argumentation as a teaching method.

Concerns about IK integration
Their seeming lack of assurance about the success of SIKI implementation should not be perceived as scepticism. This disposition may be born of their apprehension about prevailing negativity among teachers and learners and the envisaged difficulties that SIKI implementation might pose in the schools. Another pertinent concern of the participants is that teacher education curriculum implementation should not simply focus on traditional theories of science learning but on trans-disciplinary critical theories of socio-culturally sensitive teaching/learning. Another concern is the dire need to accentuate the use of argumentation as a tool for socio-culturally relevant practice in all classrooms with diverse learners. Some participants are concerned that the school curriculum and modes of assessment do not augur well for SIKI integration; hence they recommend that further revision is mandatory. All the participants agree that a change in pre-service curriculum is obligatory for widespread socio-culturally relevant practice to be the priority of teacher education institutions. They are convinced that continuous in-service teacher development should be concertedly embarked upon with strong teacher engagement in continued research. They assert that failure to do this may prove inhibitory to learners and teachers’ acceptance of IK as valid knowledge.

This paper contributes significantly not only to national but also to international discussions on socio-culturally sensitive instruction especially in science and the usefulness of argumentation for SIKI as stipulated in the new South African curriculum (RNCS). It joins myriads of researchers who to attest to the plausibility of achieving socio-culturally sensitive instruction and effectively attaining to required social justice in classrooms with diverse learners.

References


The effects of a science-IKS program on participating educators’ views regarding the implementation of an integrated Science-IK curriculum in South-Africa.

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Abstract:
A case study with a group of 19 educators enrolled in a Master’s in Science and Mathematics Education course in a South African university were exposed for two years to the following modules: an Argumentation-Discursive course (A-D course), modules on philosophy and history of science, Nature of science (NOS), Indigenous knowledge (IK) and Nature of Indigenous knowledge (NOIKS) as well formed part of a Science-Indigenous Knowledge Systems Project (SIKSP), which they attended and participated in workshops developing integrated Science-IKS materials and lesson exemplars for classrooms, specifically addressing Learning Outcome 3 (LO3) and Specific Aim 3 (SP3) as prescribed by the Revised National Curriculum Statement (RNCS) and Curriculum and Assessment Policy Statement (CAPS) for the Natural and Life Sciences curricula. A predominantly qualitative research approach was used to gain insight on the teachers’ perception with regards to the implementation of an integrated Science-IK curriculum enshrined in the RNCS and CAPS. The SIKSP course provided the educators ample opportunities to argue by being inducted into a Dialogical Argumentation Instruction model (DAIM) which is a teaching methodology based on argumentation to aid learning in science through addressing various socio-scientific issues as topics.

The findings of this study indicate: (1) the main reasons why educators oppose such an integrated Science-IK curriculum are because they know very little about IK and IKS and this affects their implementation and (2) that educators who are in favour of an integrated curriculum, highlight and impress the importance of relating science to learners’ everyday cultural experiences. Furthermore most of the educators who shifted their views from being opposed to at the beginning of the program, to in-favour of the curriculum after the program, appear to have shifted their views as a result of being exposed to the program. These shifts are explained by using the Contiguity Argumentation Theory of Ogunniyi (2007), which can account for these shifts in cognition. The implications of this study highlights the importance of developing intervention programs that address ‘demystifying’ indigenous knowledge and the development of exemplar resource materials, which teachers can access and use to prepare lessons as a matter of urgency in order for LO3 and SA3 to be actualized in classrooms.

Key Words:

Introduction
This study, motivated by Learning Outcome 3 (LO3) of the RNCS(2002) and Specific Aim 3 of the Curriculum Assessment Policy Statement (2011) documents published by the
Department of Education (DOE), is part of a much larger study concerned with determining educators’ views on the implementation and actualisation of the integrated science-indigenous knowledge curriculum as prescribed by the National Curriculum Statements and the more recent Curriculum Assessment Policy Statement (CAPS) documents for Natural, Life and Physical Sciences curricula. It proposes an integrated Science-IKS curriculum, which attempts to highlight the value of peoples’ IKS as a reflection of their wisdom and experience about their environment over the past centuries and hence should be included in science classroom discourses. The underlying assumption here is that a curriculum which reflects learners’ cultural environments are likely to be more relevant and appealing to them than one which tends to alienate them from their socio-cultural environment as was the case with the old curriculum.

In the last two decades increased emphasis has been placed in different region of the world e.g. Australia, Canada, India, Japan, New Zealand, United States and many African countries (including South Africa) on the need to include IKS in the science curriculum (e.g. DOE, 2002; Emeagwali, 2005; Garroutte, 1999; Nichol & Smith, 2000; Odora-Hoppers, 2002). The emphasis has intensified as a way of seeking alternative ways to accommodate the emergence of multi-cultural classrooms as well as a response to stem the tide of increasing food shortages and environment degradation, which are believed to be caused largely by scientific, technological and industrial activities (e.g. Corsiglia & Snively, 2001). That is, much of today’s woes are as a result of unsustainable modern science practices, such as excessive mining, deforestation, global warming as a result of uncontrolled carbon emissions in technological advanced economies. This is an attempt to look back and see how previous generations have managed to survived (sustainably) despite the absence of modern scientific methodologies and processes.

Theoretical framework

This study is underpinned by the Contiguity Argumentation Theory (CAT) of Ogunniyi (2004). The CAT is a learning theory traceable to the Platonic and Aristotelian era and deals with resolving conflicting worldviews. Plato cites examples of association by contiguity and similarity, while Aristotle in his treatment of memory enumerated similarity, contrast and contiguity as relations that mediate recollection or resolving conflicting ideas. Hobbes was well aware of the psychological import of the phenomenon of association and anticipated Locke’s distinction between chance and controlled association. However, it was Locke who introduced the phrase ‘association of ideas’ and gave impetus to modern association psychology. Following Locke’s notion of association of ideas, various scholars e.g. Berkeley and Hume were especially concerned with the relations mediating association. Berkeley enumerates similarity, contrast, causality and co-existence or contiguity as critical to resolving conflicting viewpoints, recall or learning in general. Hume talks about resemblance and contiguity in time or place and cause or effect. Contiguity Theory is therefore, a theory of the structure and organization of the mind which asserts that: (a) every mental state is resolvable into simple, discrete components and (b) the whole of mental life is explicable by the combination and recombination of these elemental states in conformity with the laws of association of ideas (Runes, 1975).

The CAT is a dialogical framework which assumes that when distinctly different ideas come together they are likely to first repel each other, seek areas of commonality and consequently coalesce to form a higher form of consciousness or deeper level of understanding than was
previously possible (Ogunniyi, 2007a). In other words, when ideas clash, an internal argument or self-conversation occurs to find a meaningful form of co-existence. CAT recognizes five cognitive categories into which ideas can move within a student’s mind when attempting to resolve conflicting worldviews: dominant, suppressed, assimilated, emergent and equipollent. An idea becomes dominant if it explains and predicts facts and events effectively and convincingly compared with a rival idea which is less so. The same dominant idea however, can become suppressed or assimilated in another context if it does not concur with the expected social norm. The emergent cognitive category of the CAT arises in a context where no prior idea exists to understand the phenomenon in question. An equipollent cognitive state occurs when two competing ideas have comparably equal intellectual force; the ideas tend to co-exist without necessarily resulting in a conflict. Again, a greater detail of the CAT has been published elsewhere (Ogunniyi, 2007a & b).

Purpose of the study
The purpose of this study was to determine the educators’ initial views regarding the inclusion of IKS in the sciences curricula contained in the National Curriculum Statements (NCS) and Curriculum Assessment Policy Statement (CAPS).

The main answers sought in this study were:

What are the views of educators regarding the implementing an integrated Science-IK curriculum?
What is the nature of the shifts in the views of educators having participated on the Science Indigenous Knowledge Programme (SIKSP)?

Methodology
Case Study:
This study design is a feasible way to obtain valid data (McMillan & Schumacher, 2001: 400). From this a few key issues are presented and analysed with supporting or negative evidence. The researcher then develops generalizations which are useful to apply to similar cases (McMillan & Schumacher, 2001: 491), which is the intention of this study. Co-researchers accommodated for triangulation.

A predominantly qualitative research approach was used to gain insight into the teachers’ perception with regards to the implementation of Science-IK in the NCS and CAPS. A group of 19 educators enrolled in a Master’s in Science and Mathematics Education course in a South African university were exposed for two years to the following modules: an Argumentation-Discursive course (A-D course), modules on philosophy and history of science, nature of science(NOS), indigenous knowledge (IK) and nature of indigenous knowledge (NOIKS) as well formed part of a Science-Indigenous Knowledge Systems Project (SIKSP), which they attended and participated in workshops developing integrated Science-IK materials and lesson exemplars for classrooms, specifically addressing LO3 and SA3. The SIKSP course provided the educators ample opportunities to argue by being inducted into a Dialogical Argumentation Instruction model (DAIM) which is a teaching methodology based on argumentation to aid learning in science through addressing various socio-scientific issues as topics.
Participants were asked to complete a 5 Item questionnaire as comprehensively as they could. This report is limited only to the educators’ responses to item 2 (b) of the questionnaire, which posed the following question:

“Were you once opposed to the Science-IK curriculum? If yes, state why and if no, state why”.

Data analysis
The responses given by 19 educators were transcribed (using Educator1 – Educator19), responses inspected, categorised and similar answers grouped and resultant emergent themes identified.

The educators’ responses were further analysed to determine if there were shifts in their views based on their initial views versus the views they held at the end of the SIKSP, and these were analysed using the Contiguity Argumentation Theory (CAT) (Ogunniyi, 2007a) in order to account for these cognitive shifts.

The analyses do not attempt to generalize the findings, but it attempts to describe the results pertaining to this group in particular. Lessons learnt can be transferred to other similar groups.

All the teachers’ comments in the tables presented below in the discussions are quoted verbatim.

Results and discussion
As indicated earlier, this study attempted to explore two key questions, viz., firstly, what were these educators’ initial views on the implementation of an integrated Science-IK curriculum, and secondly, if any there are any shifts of views, how can these be accounted for.

Table 1 below shows the percentage initial oppositional views versus initial favourable views regarding the implementation of an integrated Science-IK curriculum.

<table>
<thead>
<tr>
<th>View</th>
<th>Number of educators</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opposed initially</td>
<td>9</td>
<td>48%</td>
</tr>
<tr>
<td>Opposed at the end</td>
<td>4</td>
<td>21%</td>
</tr>
<tr>
<td>In-favour initially</td>
<td>10</td>
<td>52%</td>
</tr>
<tr>
<td>In-favour at the end</td>
<td>15</td>
<td>79%</td>
</tr>
</tbody>
</table>

As the table indicates, a significant number of the overall group (48%) were opposed to the inclusion of a Science-IK curriculum at the start when they heard of the policy directive in the National Curriculum Statements (NCS).

With the above results in mind, we will now look at answering Main Research Question1 by interrogation of the educators’ responses, through answering the following sub-questions(SQs).

Main research question 1:
What are the views of educators regarding the implementing an integrated science-IK curriculum?

SQ(a): Main reasons posited by educators initially opposed to the curriculum

The main reasons emerging from the initial nine educators who were opposed initially can be summarised in Table 4 below:

Table 4: Emergent themes accounting for opposing positions (n=9)

<table>
<thead>
<tr>
<th>Emerging Themes</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of knowledge about indigenous knowledge</td>
<td>67%</td>
</tr>
<tr>
<td>Lack of departmental training and support opportunities</td>
<td>34%</td>
</tr>
</tbody>
</table>

Table 4 indicates that their main motivation for their opposing views can be located within the following themes:
Lack of knowledge of IK
Lack of training in Indigenous Knowledge concepts and practices

**Lack of knowledge of IK**

It would appear that due to a lack of knowledge educators did not have any idea on how to go about teaching IK conceptions, which lead to a confusion as to what needs to be prioritized and what aspects of IK need to be taught. Educator 3 is one of the teachers who indicated that he felt that, “... more emphasis is on the detailing and recording of what one is going to do, and that there was no time for doing the actual job of teaching”. Educator 15 on the other hand finds it problematic to determine, “...what components can be included in the school science curriculum” and as articulated by Educator 19 that “the NCS and RNCS documents did not give me any assistance for preparing lessons for IK in Science”.

It must be noted that when Learning Outcome 3 in the Natural, Life and Physical Sciences were placed in the NCS document, positing “an appreciation for IK”, there were no materials to consult and no guidelines to teachers as to how to proceed teaching it in class; this notion is supported by Educator 4 noting due to the fact that the resources that were and are needed to integrate IK with Science are not available therefore “teachers had to design and develop their own materials to deal with the new curriculum...”, lead to other teachers ignoring the value of IK and continuing with their previous practices. Although this teacher was exposed to IK on the SIKSP programme, he still feel opposed to the curriculum due to fact that the RNCS(2002), which now gave rise to the CAPS (2011) policy document still today, lacks of guidelines and resource materials for educators to implement even now, two years later.

It appears thus that the majority of initially opposed educators indicated that they lacked the knowledge (pedagogical and content) to teach IK effectively in their classrooms, coupled to the fact that most teachers are ignorant of and hold their own biases regarding IK-practices from their own as well as the cultural IK practices of their learners and others, within their multicultural classrooms as Educator 14 posits that she opposed it “because (it) is understood IK as superstition, primitive, traditional and I felt that is no need to integrate it in the science curriculum”.

**Lack of departmental training and support**

The responses of the educators indicate that they were not trained by departmental officials on how to teach and integrate IK into Science, but they themselves had to familiarize themselves with the content of the curriculum and design their own learning materials, hence Educator 4 commented that, “...the new curriculum sometimes ended up being unsuccessful without proper support and guidance from curriculum developers, subject heads and circuit managers”. Educator 18 feels that there is not sufficient in-service training for educators to integrate IK to Science. Another aspect that she noted was the departmental monitoring of implementation which was poor highlighting that "...the officials who introduce the new
curriculum do not check if schools at grassroots level are ready for implementing the changes, ...”.

However, after Educator 9 was exposed to knowledge on IK on the SIKSP she feels that, “... this curriculum can work if teachers are trained properly”, because her participation in the SIKSP caused her to feel more confident and she had a much better understanding of how to incorporate IK into science lessons.

**In summary: Reasons for lack of implementation by teachers**

Lack of knowledge by educators themselves regarding the concept of IK, coupled to a lack of training opportunities appear to have played a significant role in shaping educators’ views right from the start. Much of this can also be understood in the context that even the departmental officials, especially the curriculum advisors were also not familiar with the concept of Indigenous knowledge at the time of the policy release, and were therefore incapable of assisting educators to make sense of it, as they themselves were ignorant of how to proceed.

**SQ (b): Main reasons posited by those educators initially in favour of the curriculum**

The overwhelming emerging theme below is based on 90% (9/10 educators) of educators’ views, which accounts for the 52% (10/19 educators) holding a positive view in favour of an integrated Science-IK curriculum. They appear to have an understanding and appreciation of the importance of relating science to the everyday life and cultural experiences of science their learners.

**IK relevance to everyday life**

This group supports the notion of the “importance of and relevance of IK to peoples’ everyday lives” and how it impacts on learners coming from differing cultural background experiences and receive science framed within their own cultural perspectives. These are borne out by statements from Educators 10, 16,17 when they warrant their positions by saying that IK “acknowledging the learners’ prior knowledge (and) help them (to) in learning to other ways of knowing the natural phenomena”, “as it is a good way to include what students know into what they learn in school therefore making it easier and relevant for them.”, and that IK “ attempt to bridge the distance between science and the lived experience of ordinary people in their communities and their cultural ways of learning (which are also scientific).”

Learners could add more value to science if they realize that it (science) is part of their daily lives, as Educator11 notes that: “...it is important to make science (students) learned in school their own”, and “in this way students will add more value to their learning of the Sciences they learn in school”. Educators 16 and 17 have also viewed the curriculum, “...as a good way to include what students know into what they learn in school therefore making it (Science) easier and relevant” and “...I understood its intent and purpose as being an attempt to bridge the distance between science and the lived experience of ordinary people...”.

Educator 13, a science lecturer notes that “I have always valued what I learnt as a child throughout my adult life. I encouraged students to explore the rich heritage of oral and written African stories, creating contexts in which learners can argue about socio-cultural issues creates an environment where learners reveal their lived experiences from which one can extract valid scientific concept”.

Interestingly, 40% (4/10) of the educators who were in-favour of an integrated Science-IK curriculum from start to finish of the program are university science education lecturers. It is assumed that their views are based on their familiarity and knowledge of and with current local and international research literature suggesting positive learning outcomes in the use of indigenous knowledge contexts in science education, thus accounting for their more insightful positive disposition towards the topic.
In Summary: Reasons by educators for being in-favour of an integrated science-IK curriculum from the start

Most of the educators in this category indicated an understanding of the importance of relating and using learners everyday experiences and knowledge to build on in their science teaching and that there is a need to appreciate, include and celebrate local practices in our integration of a Science-IK curriculum. Educators 12 and 1 so succinctly summarized the overall trend amongst this group when they say that “Although I did not know the term “IKS” at the beginning I could easily recognizes and realize that the science we have today have its feet entrenched in indigenous practices” and “My personal view has always been that much of what we know was as modern science, is actually built on IK knowledge”. This highlights the historical basis for the development of modern science, hence the History of Science (HOS), demonstrating the evolution of technological practice over time and that much of modern science have their bases in local practices.

Research question 2:
What is the nature of the shifts in the views of educators having participated on the Science Indigenous Knowledge Systems Project (SIKSP)?

The main purpose for this question is to determine the effect that the Science Indigenous Knowledge Program (SIKSP) had on the cognitive shifts of the educators’ views, especially of those educators who moved from being opposed to the curriculum initially and became in-favour later, as well as those educators whose views remained opposed from start to finish.

Analysis framework
This question will be analysed using the Contiguity Argumentation Theory (CAT) as expounded by Ogunniyi (2007a), which is a dialogical framework that assumes that when distinctly different ideas come together as in this case a new curriculum framework encompassing a Science-IK curriculum, about which they have no or little knowledge of, the new ideas are likely to first repel each other, seek areas of commonality and consequently coalesce to form a higher form of consciousness or deeper level of understanding than was previously possible (Ogunniyi, 2007a) within the educators cognitive structures in dealing with concepts.

In other words, when ideas clash, an internal argument or self-conversation occurs to find a meaningful form of co-existence. The Contiguity Argumentation Theory (CAT) recognizes five cognitive categories into which ideas can move within a learner’s, when attempting to resolve conflicting worldviews, viz., dominant, suppressed, assimilated, emergent and equipollent:

**Dominant** – An idea becomes dominant if it explains and predicts facts and events effectively and convincingly compared with a rival idea which is less so.

**Suppressed** - The same dominant idea however, can become suppressed or (c) **Assimilated** in another context if it does not concur with the expected social norm.

**Emergent** - The emergent cognitive category of the CAT arises in a context where no prior idea exists to understand the phenomenon in question.

**Equipollent** - An equipollent cognitive state occurs when two competing ideas have comparably equal intellectual force; the ideas tend to co-exist without necessarily resulting in a conflict.

Again, a greater detail of the CAT has been published elsewhere (Ogunniyi, 2007a & b).
Discussion of results:
Table 5 below illustrates a summary of the total number of educators’ initial and final views as well as the number of educators who shifted their views at the end of the SIKSP intervention.

Table 5: Educators’ views of the new curriculum before and after SIKSP intervention (n=19)

<table>
<thead>
<tr>
<th>Total Number of educators</th>
<th>Number of opposed educators</th>
<th>Number of opposed educators Remaining opposed to a Science-IK curriculum at end of SIKSP</th>
<th>Total Number of educators</th>
<th>Number of In- Favour educators Remaining In Favour of a Science-IK curriculum at end of SIKSP</th>
<th>Number of In- Favour educators Changing their view to positive about Science-IK curriculum at end of SIKSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 2</td>
<td>9</td>
<td>4</td>
<td>5</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Group 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

This discussion will specifically focus on the group of educators, who indicated an opposed view to an integrated Science-IK curriculum from the start. This is an interesting group as it appears that just more than 56% (Group1) of them changed their positions across time, while 46% (Group2) remained opposed throughout.

The discussion will proceed in two sections. The first section will look at educators who were initially opposed, but who subsequently changed their views to being in-favour of such a Science-IK curriculum over time, which we call Group1 and the second section will look at those educators who were initially opposed, and whose views remained opposed (unchanged) at the end of the program, which we call Group 2. For both these groups we will attempt to clarify the possible cognitive positional shifts or non-shifts, using the CAT.

Group1: Opposed educators changing to an in-favour view at the end of SIKSP

The results in Table 4 below, highlights the total number of educators, who initially indicated their opposition the implementation of an integrated Science-IK curriculum (n=19) and also illustrates the shifts amongst the group before and after the SIKSP intervention.

Table 6: A comparative view of cognitive shifts before and after the SIKSP

<table>
<thead>
<tr>
<th>Total Number of educators</th>
<th>Number of opposed educators Remaining opposed to a Science-IK curriculum at end of SIKSP</th>
<th>Number of In- Favour educators Remaining In Favour of a Science-IK curriculum at end of SIKSP</th>
<th>Number of In- Favour educators Changing their view to positive about Science-IK curriculum at end of SIKSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 2</td>
<td>9</td>
<td>4</td>
<td>5 (predominantly Emergent positions)</td>
</tr>
<tr>
<td>Group 1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Overall it would appear that educators in this group changed their views as a result of being exposed to the Science Indigenous Knowledge System Program (SIKSP), which exposed them to the concepts of indigenous knowledge (IK) and they ultimately became familiar with
what the curriculum actually required of them in terms of applying and implementing it as the following excerpts illustrate:

<table>
<thead>
<tr>
<th>Educator 2 - Claim</th>
<th>Backings</th>
<th>Warrants</th>
<th>CAT category</th>
</tr>
</thead>
<tbody>
<tr>
<td>I was opposed to the new curriculum because it carried new content</td>
<td>which required more training, research and new thinking I wasn’t so much equipped to face it.</td>
<td>Now I have changed my view because my participation in SIKSP has prepared me. I can now see the new curriculum as an innovation for better education.</td>
<td>Emergent</td>
</tr>
</tbody>
</table>

This educator appears to show one of the main reasons offered by most respondents that were in opposition, namely “the new content” is what caused most educators in practice to oppose the new curriculum. The educator appears to have been opposed because of this apparent lack of conceptual knowledge of indigenous knowledge and after the educator was exposed to the SIKSP, many of the knowledge gaps were addressed.

Similarly, for the two following teachers, the same appears to hold true. A lack of knowledge informed their initial opposition, but having being exposed to a program which “demystified” the concepts needed for understanding what was required of such a curriculum, they changed their views.

<table>
<thead>
<tr>
<th>Educator9 – Claim</th>
<th>Backings</th>
<th>Warrants</th>
<th>CAT category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, I was in opposition towards the new curriculum, as mentioned previously, but after the Science-IKS curriculum was unpacked during workshops, I tried to convince myself that this curriculum can work if teachers are trained properly.</td>
<td>After attending the workshops, things became more clear to me. I was also more than eager to attend and participate in these workshops. I for sure wanted to make this paradigm shift.</td>
<td>In a sense I felt guilty for being so prejudice, but who can blame me, with all the many curriculum changes we had thus far with no success. The more workshops I attended, the more, the terminology made sense, and the more I convinced myself that, perhaps this is the way forward. “Manna from heaven “ if I can call it so. I was so overwhelmed by this new teaching strategy. Imagine what this can do for my learners.</td>
<td>Emergent</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Teacher 14 - Claim</th>
<th>Backings</th>
<th>CAT category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Because I understood IK as superstition, primitive, traditional and I felt that there</td>
<td>Yes. I have changed my mind when I started realizing IK has its own nature and</td>
<td>Emergent</td>
</tr>
</tbody>
</table>
It would appear from the selected above excerpts, that the educators in Group 1 that have changed their positions from pre-opposed to a post-in-favour view, have noted that it was their interactions on the SIKSP program that influenced their shifts in position, as the program developed new understandings and insights of what the Science-IK curriculum entails and what IK encompasses. According to the Contiguity Argumentation Theory, these respondents have developed an emergent view – having being exposed and having developed new understandings on a topic/concept of which they had no prior knowledge. The conflict that arose as a result of what notions they initially held versus what they later internalised as a result of the new “knowledge” which they have acquired, resulted in them shifting their cognitive position on the concept(s) in question.

**In summary: Opposed educators changing to an in-favour view at the end of SIKSP**

According to the Contiguity Argumentation Theory (CAT), it would appear that all of the educators in this particular group (having moved from opposed to an in-favour view) have shifted from a dominant view of science to an emergent view on IK, that is, changed their position as a result of new conceptual understandings gained of the concept IK which they did not have before.

**Group 2: Educators remaining opposed at the end of the SIKSP**

<table>
<thead>
<tr>
<th>Total Number of educators Opposed initially to Science-IK curriculum before SIKSP</th>
<th>Number of educators Remaining opposed to a Science-IK curriculum at end of SIKSP</th>
<th>Number of opposed educators Changing their view to positive about Science-IK curriculum at end of SIKSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Group 2</td>
<td>Group 1</td>
<td></td>
</tr>
</tbody>
</table>

The following excerpts shows the views and positions held by 3 out of the 4 educators in Group 2, who have remained opposed to the inclusion of a Science-IK curriculum from start to finish of the program. We will attempt to give some insights into their positions based on the CAT framework.

<table>
<thead>
<tr>
<th>Educator4 - Claim</th>
<th>Backings</th>
<th>CAT category</th>
<th>Equipollent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes, the NCS (2003) curriculum depends on kind of resources that were not readily available to teachers at schools. Teachers had to design and develop their own resource materials to deal with sometimes ended up being unsuccessful without the proper support and guidance from curriculum developers, subject heads and circuit managers</td>
<td>I have not change my view because the amended NCS (2003) has launch the CAPS (2011) policy statement document in January 2011 into schools, and include IKS under specific</td>
<td>Arguments for view put forward to substantiate opposing the curriculum view is intellectually valid and applicable.</td>
<td></td>
</tr>
</tbody>
</table>
the new curriculum, aim 3 to be implemented in the assessment of learners again without any proper guidelines and resources materials. This will only cause teachers to ignore the value of a science-IK curriculum in the classroom.

<table>
<thead>
<tr>
<th>Educator6 - Claim</th>
<th>Backings</th>
<th>CAT category</th>
</tr>
</thead>
<tbody>
<tr>
<td>I knew the curriculum had failed in the USA and Australia, so somehow I thought it was going fail in South Africa.</td>
<td>In addition, I also realized the teachers were not ready for this type of curriculum especially the section where the integration of science and IKS is required.</td>
<td>Equipollent</td>
</tr>
<tr>
<td>I still feel teachers need to be professionally developed on how to integrate science and IK.</td>
<td>Argues for both sides of the issue – holding both valid views</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Educator18 - Claim</th>
<th>Backings</th>
<th>CAT category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initially, as with previous curriculums there are skepticisms when there is introduction in to the new curriculum</td>
<td>It is merely the fact that there are insufficient workshops for teacher-training especially in relation to IKS if any.</td>
<td>Equipollent</td>
</tr>
<tr>
<td>Another challenge is that the officials who introduce the new curriculum do not thoroughly check if schools at grassroots level are ready for implementing these changes, let alone provision of adequate resources</td>
<td>Argues for both sides of the issue – holding both valid views</td>
<td></td>
</tr>
</tbody>
</table>

The educators in this group appear to acknowledge the Science-IK curriculum, however, they are offering just as valid arguments against the implementation of such a curriculum based on their own experiences, citing logistic constraints and knowledge gaps experienced by teachers that would make it difficult to implement such a curriculum.

**In summary: Opposed educators remaining opposed at the end of the SIKSP**

The most common arguments raised by this group are issues around logistic lack of training opportunities for teachers to become knowledgeable about IK and integration and the past failures of the OBE curriculum in other countries. The Contiguity Argumentation Theory (CAT) would categorize them as holding *equipollent views*, defined by the CAT as a cognitive state in which occurs when two competing ideas have comparably equal intellectual force; the ideas tend to co-exist without necessarily resulting in a conflict. As these educators have experienced the program just as those of Group 1 educators and have experienced the essence of what IK is all about, they still have an opposing view, albeit it would appear as a
series of excuses; they could in essence hold an equally valid view on the idea/concept of an integrated Science-IK as well as a modern science curriculum, without experiencing an apparent cognitive conflict between the two.

**Conclusion**

It appears from the results of this study that the views of 47% (09/19) educators initially opposed to an integrated Science-IK curriculum educators, changed to 21% (04/19) opposed to in-favour of such a curriculum, it is noteworthy that all of the shifts from opposed to in-favour at the end the program can be accounted for through the Contiguity Argumentation Theory, which categorised these shifts as moving from a dominant science views to emergent views, occurring as a result of initial educator lack of knowledge about IK, but having being exposed to a program that unpacked the conceptual and nature of indigenous knowledge, they changed their views accordingly.

As most educators in practice have been inducted into a science worldview and how it operates during their studies as well as during their training, it is difficult to expect teachers to be instantly familiar with multiple cultural perspectives of their learners and to be able to integrate the two worldviews seamlessly. As they find themselves in multi-cultural classrooms across South-Africa, they have to become knowledgeable about their own and as well as their learners cultural perspectives on issues of everyday “science” conceptions, in order to make meaningful integration of modern science and local indigenous “science” conceptions meaningful. This is supported by the views of those 52% (10/19) educators who have supported such a curriculum from start to finish, highlighting the educational value of making science relevant to learners’ everyday experiences through integrating it with learners’ indigenous knowledge conceptions.

It is also worthy to note that the main reasons for educators opposing the curriculum were around issues of lack of knowledge around IK as well as lack of official training and lack of officials’ guidance on the policy directive, including a lack of exemplar materials for educators to use and consult for lessons addressing LO3. These factors need to be addressed as a matter of urgency in order for educators to start implementing Learning Outcome (LO3) in the NCS and Specific Aim 3 (SA3) in the CAPS.

The 4 educators whose views remained the same from start to finish are also worthy of mention. Their sentiments echo to a large extend the views of many educators out there who are faced with the same dilemma as to how to go about addressing LO3 and SA3, but they are so swamped with logistics and the urgency of completing the current curriculum, which at the moment appears to exclude integrating Science-IK meaningfully, that although it would appear that integration would be a good idea, it would be just easier for them just to highlight the “problems” that exist which would make it “difficult” for them to implement and thus retain the status quo. Further exploration in this regard would yield meaningful insights into how educators operationalize innovations in curricula.

**References**


Department of Education (2002). Revised National Curriculum Statement Grades R-9


The Integration of ICTs in the teaching and learning of mathematics, science and technology subjects in Swaziland secondary schools

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Abstract
The opportunities brought by Information and Communication Technology (ICT) have opened up new learning environments which can be utilized by educators in the teaching and learning of Mathematics, Science and Technology (MST) subjects. Literature shows that the quality of teaching and learning can be enhanced through effective integration of ICTs. This pilot study explores the trends in the integration of ICTs in the teaching and learning of MSTs in Swaziland schools. Specific focus is on ascertaining if teachers and learners integrate ICTs in teaching and learning of MSTs.

This is an exploratory study which seeks to understand the use of ICT tools in the teaching and learning of MSTs. Data collection was through questionnaires administered to practising teachers and learners in three Senior Secondary schools, purposively selected on the basis of availability of the ICT programme in the schools. Analysis of data revealed the main findings to be shortage of ICT tools, lack of knowledge, underutilisation and inefficiencies in the use and integration of ICTs in the teaching and learning of the sciences. No school plan of action for using the ICT tools in the MSTs was found in all the three schools. It can be concluded that there is limited integration and access to ICT tools and infrastructure by both learners and teachers in the Mathematics, Science and Technology Education (MSTE) classrooms in Swaziland.

Key words: ICT- Information and Communication Technology; MST- Mathematics, Science and Technology

Introduction
Curriculum integration is not a new method of organising for instruction. Educators first explored the concept of integrating curriculum in the 1890s attributed to the work of Dewey and Kilpatrick (Forgarty 1991, Vars 1991, Loepp 1999, Heggart, 2007 and Mustafa 2011). Curriculum integration can be understood from different perspectives. Numerous researchers such as Jacobs 1989, Vars 1991, Beane 1997, Alberta Education 2007 have referred to an integrated curriculum as interwoven, connected, thematic, interdisciplinary, multidisciplinary, trans-disciplinary, correlated, linked and holistic. In essence, there are many ways in which curriculum can be integrated. The different focus areas in integration are determined by the rationale for the integration itself. For example, if the integration is about connecting related themes within a discipline, its main focus will be thematic and correlated. However, it is imperative to first establish what integration is about.

Curriculum integration is not just a cluster of related learning outcomes. It is about the selection of learning experiences to the extent to which they promote progress or broaden and confirm understanding (Alberta Education, 2004). Brazee and Capelluti (1995) assert that curriculum integration is based on a holistic view of learning and recognizes the necessity for learners to see the bigger picture rather than to require learning to be divided into small pieces. Integrative curriculum ignores traditional subject lines, while exploring questions that are most relevant to learners (Wang, 2001). In view of the different perspectives by different scholars, we understand curriculum integration as the blending of subject areas such that the
different parts are not discernible. Integration incorporates the idea of unity between forms of knowledge and the respective disciplines put forward by Loepp (1991). Of essence is to note that integration happens at different levels since in practice it takes many forms.

The focus of this study is on the integration of ICTs into the teaching of MST subjects in Swaziland. This in accordance with the dictates of the Ministry of Education and Training (MOET) and Government of Swaziland aspirations articulated in the National development strategy NDS -Vision 2022 GoS (1997) and National Information and Communication Infrastructure (NICI) Policy that education should incorporate ICTs. The integration of ICTs into teaching and learning is not a new concept. It may be as old as other technologies such as radios or televisions. However, with the advancement of emerging technology, such as web technology and increase in information, ICT integration has increasingly become important to educators.

ICT is basically a technological tool. It consists of hardware (such as computers, digital cameras), software (such as Excel, Power Point), networks and media for collection, storage, processing, transmission, and presentation of information (voice, data, text and images) as well as relative services (Ministry of Education and Training, 2010; UNESCO 2005; World Bank 2002). In the educational context, it mainly refers to various resources and tools (software) presented on the computer. Examples of such include Computer Aided Instruction (CAI) software packages.

The use of ICTs as a teaching and learning tool in schools has its basis on a belief, that ICTs have a positive impact on the teaching and learning process. This is owed to ICT as being interactive in nature. Research has shown a positive impact of ICT in both teaching and learning (Kulik, 1994, Baker, Gearhart, and Herman, 1994 and Sivin-Kachala, 1998, the Software Information Industry Association SIIA (1999) in Newhouse (2002)). They argue that ICT makes learning more learner-centred, encourages cooperative learning, stimulate increased teacher-learner interaction and promotes critical thinking, which subscribe to constructivist theory of learning. Moreover, educators commonly agree that ICT has the potential to improve student learning outcomes and effectiveness if it is used properly (Wang, 2001in Wang 2007).

As a result different education systems are attracted to providing ICT-based educational programmes. In this light, Newhouse, (2002) articulates the rationales put forward by a lot of countries for implementing ICT in schools as being: Improve student achievement of learning outcomes across the curriculum, Provide students with adequate ICT literacy, and Increases the efficiency and effectiveness of schools as organizations.

Problem statement
In the Swaziland context, the MST subjects at Senior Secondary level include Mathematics, Science, Agriculture, Design and technology, Consumer Science and ICT. The expectation, according to the Draft ICT Policy is that ICT should service the teaching and learning of the MST subjects (MOET 2010). This implies that the teaching and learning of the MST subjects should integrate ICTs. Integration in this context means ICT tools being effectively integrated in the pedagogy design of the subjects for effective learner-centred teaching and learning. It is not enough to have the ICT tools available if not systematically fitted into the curriculum, not the curriculum into the ICT tools (Mandell, Sorge and Russell 2002 in Wang & Woo 2007). Furthermore government’s commitment in integrating ICT into education is evident through numerous initiatives introduced in different units of the ministry of education. The
NCC, a government department responsible for the development of schools curriculum in the country has to embrace the ICT integration. The mathematics, science department at NCC has since been expanded to include the ICT component. The expectation is for the department to integrate the ICT into the MSTs curriculum materials. However it is not possible to do that without the knowledge of the trends in the integration of ICTs in schools, hence the purpose of the study.

**Purpose of the study**
This study explores the use of ICTs in the teaching and learning of MSTs. Specifically it is to ascertain whether teachers and learners integrate ICTs in teaching and learning of MSTs. To attain this purpose the following research questions directed the study.

What ICT tools are used in the teaching and learning of the MSTs? 
How are the ICT tools integrated in the teaching and learning of MSTs? 
What challenges are faced by schools with regard to the use of ICT tools in teaching and learning of MSTs?

**Status of ICT in Swaziland**
The Ministry of Education and Training supports the inclusion of ICT in the curriculum. Indicators of such support are seen in the number of partnerships that government has got into resulting in initiatives to facilitate the introduction of ICT in the schools since 1998 (Dlamini *et al* 2012). Some of the partnerships include: The Computer Project (funded by the Republic of China – Taiwan) equipping schools with IT equipment and other accessories, The Prevocational Project (funded by the African Development Bank - ADB) for facilitating the teaching of ICT in business studies, Computer Information System Company (CISCO) Academy Programme (A partnership between the University of Swaziland and Cisco Systems Incorporated, with the assistance of UNDP) whose aim is to reduce the digital divide by training locals on Internet technologies, the Computer Education Trust (CET) for provision of ICT skills in education by funding in-service training for teachers as well as develop some teaching learning materials (National Information and Communication Infrastructure (NICI) Policy of 2005). Based on the recommendations of the NICI policy, the ICT Education draft policy (2010) was developed which acknowledges the integration of ICT in the teaching and learning process for all learners across all subject disciplines.

**Integration of ICTs**
According to Earle (2002) integration depicts completeness. This means all essential elements of a system are combined together to make a unit. In integrated teaching and learning, simply referring learners to a collection of ICT tools such as web-based resources, CD-ROM programmes or subject specific software is limited ICT integration. This statement suggests a need for a more systematic approach of integration to render ICT as an effective teaching and learning tool. ICT integration in this paper is broadly defined as a process of using any ICT tools to enhance effective teaching and learning of the MSTs.

Various models are used for integrating ICT into different subject disciplines. This depends on the purpose and magnitude of integration. For instance, Fogarty (1991) in her book, The Mindful School, discusses 10 useful models of integration namely:- Fragmented, Connected, Nested, Sequenced, Shared, Webbed, Threaded, Integrated, Immersed and Networked. Some of their components would apply to the integration of ICT into MSTs. However, these models are not specific to the integration of ICT into the MSTs.
Yuen, Law, Wong (2003) cites three models that are specific to the integration of ICT into the curriculum. These models are the technological adoption model, the catalytic integration model and the cultural innovation model.

The Technological Adoption Model which Yuen, Law, Wong (ibid) refer to as Model A conforms to the managerial perspective in a school. It pertains to the adoption of technological infrastructure and management of ICT in a school (Kearsley, 1990).

The Catalytic Integration Model (Model B) is prominently used in ICT curriculum innovation in schools. It targets influencing the pedagogical practices of the teachers including the administration such that learning is task-based, problem-based and subscribes to social constructivism. This model is more advanced than the former in the sense that teachers change their practice and roles to accommodate ICT in order to achieve the educational goals through the use of ICT as a catalyst.

The Cultural Innovation Model (Model C) is a model that encourages the integration of ICTs into other subject disciplines without laid out guidelines. Usually, individual interest of teachers and learners is the driving factor behind the integration of ICTs. The strength of this model is encouragement rather than coercion by the administration. Minimal supervision is an important feature of this model. The integration conforms to the school tradition and culture. Such a model would allow learners to discover and try-out new things on their own and at free will.

Another model which also underpins this study is the three-tier model of ICT integration expounded by Wang & Woo (2007). This model is specific to the integration of ICT. It is more or less the same as the Catalytic Integration Model by Yuen, Law, Wong (2003) except that this one is comprehensive about the ICT integration.

The three-tier model postulates that ICT integration can happen in three areas: curriculum (macro), topic (meso), and lesson (micro), as shown in Figure 1.
Kalaycı and Ümmühan (2011), in order to understand this process in a holistic way with different angles this model proved suitable. Unlike the Catalytic Integration Model, this model specifies the possible areas in which ICT integration can take place. It specifies what should actual happen when integration is done at the broader (macro), the intermediate (meso) and within at specific lesson (micro) levels. Furthermore, the three-tier model appears relevant in the field of research in which it is widely used to explore and understand matters of ICT integration. This is illustrated in the next section where a few studies are highlighted.

Kalayci (2011) conducted a case study on the ICT integrating at the faculty level using some components of the three-tier model in Turkey. Kalayci’s study investigated how ICT is integrated at the faculty level in an institution. Findings of this study revealed that the faculty did not have written ICT policies on the web site and written goal in the quality documents of the faculty of education. Another study which used the three-tier model was by Velazquez (2008) focusing on testing predictive models of technology integration in Mexico and the United State of America (USA). Findings revealed more than 90% variance in classroom technology integration due to a linear combination of a teacher's attitude or Will, technology proficiency or Skill and access to technology Tools. Another study by Bahati (2010) looked at the pedagogical integration of ICT in teaching and learning at Kigali in Rwanda. The findings show that while Kigali Institute of Education has made the commitment to use ICT in supporting and facilitating the successful pursuit of its mission, there was no coherent and detailed strategy or framework to support the use of ICT pedagogical tools in the teaching and learning.

Despite the many studies that have been reviewed on ICT integration, very few if any are specific to the Sciences. Out of these, none could be obtained on the integration of ICT in MSTs in Swaziland schools. A few studies on the subject investigate the status of ICT in Swaziland and are to a large extent done by donor agencies such as the World Bank in 2010. Dlamini (2012) investigated the extent to which the ICT tools are integrated in the learning process in general in which he found varied supply of basic tools in schools, and varied abilities among teachers in using the tools. Dlamini, Mashwama and Thwala (2012) investigated issues and challenges faced by the ICT curriculum reform. They found that schools face challenges of resources and capacity building, as well as an unstandardized curriculum in schools. The main focus regarding ICT in the country is towards the establishment of the Technology Park which focuses on the use of ICT in the commercial sector of government. This is despite the government commitment in introducing and integrating ICT in the schools as articulated in the NICI Policy and the NDS. It is however noted that the education policy environment is very poor as noted by the World Bank (2010) referring to it as a critical weakness in the efforts to improve curriculum relevancy. Nonetheless, the Ministry of Education and Training supports Computer literacy programmes in which schools have enrolled to an extent of supplying computers to some government schools and establishing an inspectorate unit in the Ministry of Education and Training Headquarters as well as expanding the Mathematics Science department in the curriculum design component of Ministry of Education and Training to include an ICT wing.

**Role of ICT in teaching and learning**

Impact studies in ICT point at a lot of advantages brought by ICT that improve the quality of teaching and learning. According to Tinio, 2002, ICT promotes learner-centred approaches which motivate the learner to engage in the learning process. She further highlights important skills acquired during the learning process which include digital literacy skills, scientific literacy skills, cultural literacy, inventive thinking, effective communication and adaptability.
to name a few. ICTs enhance the acquisition of basic skills and concepts which are the foundation of higher order thinking skills and creativity.

Research evidence indicates that technology has great potential to link learners to various information sources, enhance collaborative learning, and affords teachers more time to facilitate the teaching and learning process (Moallem, 2003; Roblyer, Edwards, & Havriluk, 2004; Wilson & Lowry, 2000). Integrating ICT into teaching and learning has therefore become paramount in education.

Computers and other ICT tools as asserted by Dlamini, Hlophe, Mhlungu and Simelane (2011), are instruments that can be used by students to interact independently in classroom instruction which is inherent in Vygotskyian constructivism theory which advocate for learner-centred teaching and learning.

**Methodology**

This is a pilot study which employs a case study design to explore the trends of the integration of ICTs in the teaching and learning of MSTs for further investigation in this subject. This design was chosen in order to gain understanding of the situation in the integration of ICT tools for teaching and learning purposes in the MST subjects. The focus was to obtain the teachers’ and learners’ perspectives in this regard.

Three senior secondary schools were conveniently selected in the Manzini region to participate in this pilot study. The schools were purposefully selected based on the availability of the ICT programme in the school. Respondents of the study consisted of practising teachers of the MST subjects at senior secondary level. One teacher per subject was chosen as a respondent. Two high-performing learners in each of the MST subjects available in the schools were also selected as respondents. High performance in MSTs was regarded as an indicator for motivation, dedication and resourcefulness on the part of the learners. The assumption was that high performing learners are most likely to integrate ICT tools in their learning.

The respondents in each school were given questionnaires to complete. The development of the questionnaires was influenced by the details of what happens in the macro, meso and micro levels of the three-tier model of integration. As such, some items in the questionnaires enquired about availability of ICT tools, the use of tools within a subject, topic or within a lesson. For the teachers’ questionnaire there were items about whether teachers had a plan of action in implementing ICT and possible challenges they face in using ICT tools in their teaching. The learners’ questionnaire also included items relating to their initiativeness in using ICT tools and enjoyment. In addition, the development of the questionnaire was informed by instruments used in the Evaluation Department of the National Curriculum Centre (NCC) which also did face validation of the questionnaires. For content validation, the instrument was given to ICT specialists at NCC and at a teacher training college. The reliability of the questionnaires was being tested in this study as it is a pilot. Upon analysis of the responses in the questionnaires, the instruments proved reliable as the interpretation of the different items in the questionnaires by respondents were similar.

The analysis of data in this study involved grouping data according to the pre-coded themes that included general issues about the availability of ICT tools and pedagogic use of ICT tools in the teaching and learning process. The interpretation of results was done following the Wang and Woo model of ICT integration (2007).
Limitation of the study
The use of one type of data collection instrument (questionnaire) was limiting as it was not possible to get an in-depth understanding of the integration of ICT tools in MSTs. The initial plan was to also conduct an interview of the respondents. However, this could not happen due to a prolonged teachers’ strike action during data collection. Since this was a pilot study, the research team went ahead to analyse the available data to get a feel of what was happening in the teaching and learning of the MSTs regarding this matter.

Presentation of results
The findings are presented in tables according to the MST subjects offered in the participating schools. The results were organised into themes showing available ICT tools and how they are used by both teachers and learners in the different schools. The findings are presented for each school separately. Free response data is reported narratively below each table. The learners’ responses are presented before that of the teachers for each school.

Tables 1, 2 and 3 show results obtained from learners and teachers from School A. Tables 4, 5 and 6 show results obtained from learners and teachers from School B; and tables 7, 8 and 9 show results obtained from school C learners and teachers.

Table 1: Availability and use of ICT tools by learners in school A

<table>
<thead>
<tr>
<th>Subject Studied</th>
<th>ICT Tools used in Subject</th>
<th>ICT Tool Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>computers, cell phone, camera, Television (TV), radio, calculator</td>
<td>Research information through internet Calculations</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Calculators, Camera, computers, TV, Radio, Projectors</td>
<td>Calculations Use projectors for documentaries Research information on internet</td>
</tr>
<tr>
<td>Design and Technology</td>
<td>Computers, calculators, camera</td>
<td>Camera for taking project photographs Computer used for printing photographs Typing projects</td>
</tr>
<tr>
<td>Consumer Science</td>
<td>Calculators, computers, TV</td>
<td>Research on the internet Watching relevant scenarios on TV</td>
</tr>
</tbody>
</table>

Concerning access to ICT tools, Table 1 shows that learners in school A had access to computers and calculators as ICT tools in all the four departments. Learners in three out of the four subject departments, reported to have access to TV. Other learners in the two departments, had access to a camera.

The questionnaire required the learners to state what they used the mentioned ICT tools for. In school A, learners reported to use computers for accessing information from the internet and also typing their projects. They used calculators to carry out calculations. Cameras were used for taking photographs needed for their Design and technology projects.
Table 2: School A learners’ responses to structured items in questionnaire

<table>
<thead>
<tr>
<th>Item in Questionnaire</th>
<th>Responses</th>
<th>Number of learners (n = 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is it easy to access ICT tools whenever you need them?</td>
<td>I am free to access ICT tools whenever I need them</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>I am not free to access ICT tools whenever I need them</td>
<td>1</td>
</tr>
<tr>
<td>Do you enjoy using the ICT tools?</td>
<td>I enjoy using ICT tools</td>
<td>8</td>
</tr>
<tr>
<td>Are you free to use self taught strategies when using the ICT?</td>
<td>I am free to use self-taught strategies</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Not free to use self-taught strategies</td>
<td>5</td>
</tr>
<tr>
<td>Are you supervised by your teacher each time you use the ICT tools like computers?</td>
<td>Always supervised</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Not always supervised</td>
<td>2</td>
</tr>
</tbody>
</table>

From the learners’ responses in Table 2, it was gathered that seven out of eight learners were able to access ICT tools whenever they needed them. Four of the learners reported to have acquired basic computer skills from friends and self-teaching while the other four reported to have acquired skills from their teachers. All of the learners said they enjoyed working with computers. Three learners attested to have had liberty to use self-taught strategies during lessons while the other five had no liberty to use alternative self-taught strategies. About supervision, six learners reported that they are always supervised when working with ICT tools such as computers while the other two reported to the negative.

Part of the questionnaire in the section of open-ended items required learners to state the advantages of using ICT tools in their learning. All the learners presented the advantages of using computers as being able to work easier and faster, making it easier to find information and broaden their understanding of concepts.

Responses to the teachers’ questionnaire in School A are reported in Table 3.

The results in the Table 3 reveal that all the teachers in school A have access to computers and calculators. Teachers in two departments had access to TV. They also reported using computers for researching information on the internet and preparing notes, tests and examinations. Teachers in the Design and Technology department also use computers to type and print the learners’ projects.

Table 3: Availability and use of ICT tool by teachers in school A (n=4)

<table>
<thead>
<tr>
<th>Subject Taught</th>
<th>ICT Tools Available</th>
<th>ICT tool Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>Computers, calculator, Overhead projector</td>
<td>Research information through internet Calculators used for calculation in mathematics Use overhead projector when teaching Preparing notes</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Calculators, computers, TV, Overhead Projector</td>
<td>Prepare notes, tests and examinations Type final write ups of the students projects</td>
</tr>
</tbody>
</table>
The free responses by the teachers also revealed that schools had rules set by the department on when and how to use the ICT tools like the computers, TV and cell phone. The participation of the learners in setting those rules was not evident in the responses. Although teachers reported to have ICT facilities in their schools, they stated that they were inadequate. As such most of the time, computers are used for the ICT subject only. According to the teachers, learners freely use computers during ICT lessons. They are not free to use ICT tools (particularly computers) at any time for security reasons unless they are supervised.

The questionnaire also solicited challenges teachers faced in using ICT tools in the MST subjects. The results revealed lack of in-service training for teachers, inadequate computer tools, poor maintenance of computer tools and lack of time for learners to go and use computers on their own for the MSTs.

Results from school B are presented in Table 4.

<table>
<thead>
<tr>
<th>Subject Studied</th>
<th>ICT tools used in Subject</th>
<th>ICT tool use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>Computers, Calculators</td>
<td>Research information through internet Calculations</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Calculators, computers, camera, Projector</td>
<td>Calculations Camera for taking pictures to be used in Agriculture project Projector for visual learning; display objects that are not available in the school. Research information on internet especially for the project.</td>
</tr>
<tr>
<td>Design and Technology</td>
<td>Computers, calculators, camera</td>
<td>Camera for taking photographs for the school project Researching information for school projects Typing projects</td>
</tr>
<tr>
<td>Consumer Science</td>
<td>Calculators, computers, TV</td>
<td>Research on the internet when doing projects</td>
</tr>
</tbody>
</table>

In school B, learners had access to computers and calculators in all the four departments. However, in two departments (Design and Technology and Consumer Science), learners had access to a digital camera to take photographs of their projects. The learners attested to using computers for accessing information from the internet and typing projects just like in school A. They also use calculators to carry out calculations in all subjects. The responses to structured questions in the learners’ questionnaire are presented in Table 5.
The results in Table 5 show that all the learners in school B had free access to ICT tools and were taught computer skills by their teachers. All learners in this school also said they enjoyed using computers. Most learners (5) reported to be unable to access computers whenever they needed. Concerning supervision, learners reported to have been always supervised when working with computers.

In their free responses, learners reported that due to the shortage of computers in the school, they could not gain access to use some ICT tools like computers whenever they wanted. As such they were supervised each time they used computers to ensure that they were doing school work.

Concerning the advantages of using ICT tools, learners reported that it made their work easier and efficient enabled them to get more information from the internet and assisted them in making their project work neat and presentable.

Table 6 reports on the availability of ICT tools based on two teachers who responded to the questionnaire. The other two in this school could not consent.
Teachers in the two departments reported to have access to computers and calculators. They used these tools for carrying out research and setting tests.

The teachers in their free responses also stated that they set rules for the use of the ICT tools as departments without the involvement of learners. They also stated that the ICT tools, particularly computers, are not adequate for all learners. Both teachers were in agreement that learners enjoyed using ICT tools. The teachers also stated that learners could not access ICT tools at any time they needed to and this was due to the inadequacy of the tools and the high numbers of learners per class. The use of computers was said to be scheduled to accommodate all learners. However, calculators are often adequate as compared to other ICT tools. Tables 7 and 8 show results obtained from School C for learners and Table 9 shows results from teachers for School C.

Table 7: Availability and use of ICT tools by learners in school C

<table>
<thead>
<tr>
<th>Subject Studied</th>
<th>ICT tools used in Subject</th>
<th>ICT tool Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>Computers, Calculators</td>
<td>Research information through internet Calculating in maths and science</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Calculators, computers</td>
<td>Calculations and solving Mathematical problems Typing projects in agriculture</td>
</tr>
<tr>
<td>Consumer Science</td>
<td>Calculators, camera</td>
<td>Research on the internet Camera for taking project pictures</td>
</tr>
</tbody>
</table>

Table 7 shows only three MST subjects since Design and Technology was not offered in the school. Pertaining to access to ICT tools, Table 7 shows that learners in school C had access to computers and calculators in all the three departments; and a camera in one department. In all the departments the tools were used to conduct research, do calculations when solving mathematical problems and typing of projects. The camera was used for taking photographs needed for their Consumer Science projects. Tables 8 shows results obtained from learners in School C for the structured items.
From the learners’ responses, Table 8 shows that half the number of learners were able to access ICT tools freely whenever they needed to. One of the learners reported to have acquired basic computer skills from friends and self-teaching while the other five reported to have been taught the skills by their teachers. All the six learners said they enjoyed working with ICT tools. Five learners attested to have had liberty to use self-taught strategies during lessons. All six learners reported that they were always supervised when working with ICT tools such as computers.

In the open-ended section of the questionnaire, learners were required to state the advantages of using ICT tools in their learning. All the learners presented the advantages of using computers as being able to work easier and faster, and find information to problems in a faster way, and broaden their understanding of concepts. Table 9 reports on the availability of ICT tools based on four teachers who responded to the questionnaire.

**Table 8: School C learners’ responses to structured items in the questionnaire**

<table>
<thead>
<tr>
<th>Item in Questionnaire</th>
<th>Responses</th>
<th>Number of learners (n = 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is it easy to access ICT tools whenever you need them?</td>
<td>I am free to access ICT tools whenever I need them</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>I am not free to access ICT tools whenever I need them</td>
<td>3</td>
</tr>
<tr>
<td>How did you learn the skill for using the ICT tools?</td>
<td>I taught myself computer skills and from friends</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>I learned them from the teacher</td>
<td>5</td>
</tr>
<tr>
<td>Do you enjoy using the ICT tools?</td>
<td>I enjoy using ICT tools</td>
<td>6</td>
</tr>
<tr>
<td>Are you free to use self taught strategies when using the ICT?</td>
<td>Free to use self-taught strategies</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>no response</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Not free to use self-taught strategies</td>
<td>5</td>
</tr>
<tr>
<td>Are you supervised by your teacher each time you use the ICT?</td>
<td>Always supervised</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Not always supervised</td>
<td>0</td>
</tr>
</tbody>
</table>

**Table 9: Availability and use of ICT tools by teachers in school C (n = 3)**

<table>
<thead>
<tr>
<th>Subject Taught</th>
<th>ICT Tools Available</th>
<th>ICT tool Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>Computers, calculator, Overhead projector, TV, laptop</td>
<td>Research information for assignments</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Watch educational videos and slides for teaching</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Use transparencies in teaching</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Calculator used for calculations</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Computers, calculator, TV, laptop</td>
<td>For storing and retrieving information</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Data tabulation and Analysis of information</td>
</tr>
<tr>
<td>Consumer Science</td>
<td>Calculators,</td>
<td>Research on the internet</td>
</tr>
</tbody>
</table>
Teachers in the three departments reported to have access to computers, overhead projector, TV, laptop and calculators. They used these tools for carrying out research, designing menu cards, typing projects, data tabulation, calculations and analysis as well as setting tests.

The teachers in their free responses stated that they had rules for using the ICT tools which were set by the administration without the involvement of learners. They also stated that the ICT tools, particularly computers, are not adequate for all learners, and as a result learners end up being referred to commercial service providers for the typing of their projects and the designing of menu cards. All the teachers were in agreement that learners enjoyed using ICT tools. The teachers also stated that learners do not have access to ICT tools especially computers as the ICT laboratory is always occupied by the ICT learners. Hence the facility is inadequate for the large numbers of learners per class.

Discussion and conclusion
It is learnt from the results that teachers and learners have access to ICT tools in the three schools. It also transpired from the results that in these schools the access is limited with computers as there is always a shortage due to high numbers of learners in the classrooms. This is in response to the first research question about the availability of ICT tools in the schools. As such learners are often under supervision when using computers in these schools. Despite the shortage of computers, it does appear that computers are a vital tool for teaching and learning as they are used for searching for information and typing of learners’ projects. For instance, learners distinctly pointed out the usefulness of computers in carrying out their projects in Design and technology, Agriculture and Consumer Science. These included getting information for the projects and preparing the projects write-up and designing.

Attesting to such importance are studies by Kulik (1994), Baker, Gearhart, and Herman, (1994) and Sivin-Kachala (1998), Newhouse (2002), Wang (2007) who argue that ICT makes learning more learner-centred, encourages cooperative learning, stimulate increased teacher-learner interaction and promotes critical thinking.

Drawing from Wang and Woo (2007) three-tier ICT integration model, there is evidence of some integration of ICT in these MSTs, and it is limited to the Meso and micro tiers of the model. It is also not quite organised in terms of provision within the institutions. Regarding the second research question, the limited and haphazard ICT integration in the MSTs as depicted by the results is a cause for concern. This is on the basis that learners are deprived of the development of skills such as digital literacy skills, scientific literacy skills, cultural literacy, inventive thinking, effective communication and adaptability as articulated by Tinio (2002). Moallem, (2003), Roblyer, Edwards, & Havriluk, (2004) and Wilson & Lowry (2000) reaffirm the importance of ICT integration in the teaching and learning of MSTs.

Further noted from the results is that none of the learners and teachers in all the schools mentioned the use of computers in any of the natural sciences offered in these schools. The tendency is to teach ICT as a separate entity.

It is therefore concluded that though ICT tools are available in these schools, they are under-utilised. This extends to specific ICT tools being restricted to specific subject disciplines and yet they could be used across disciplines as learning tools as suggested by Wang and Woo (2007) and Mustafa (2011).
The probable cause for the inadequate use of the ICTs which the third research question addresses could be attributed to lack of training on the part of the teachers on how to integrate ICTs in the MSTs in particular the natural sciences. Shortage of ICT tools to a large extent contribute to the limited use and haphazard integration of ICTs in MSTs. Linked to the inadequacy of ICT resources in the schools are the large number of learners and the restrictive school procedures in accessing ICT tools, thus prohibiting the success of ICT integration in the MSTs.

**Recommendations**

The ministry of education and training still has a major task to provide ICT tools, build infrastructure and capacity for teachers, curriculum personnel, in-service providers and inspectorate.

Teachers need to be trained on how to use ICTs for teaching and learning. This ranges from how to use a calculator proficiently to how to use a computer effectively.

There is a need for the ministry of education and schools to equip their departments with ICT tools to enhance the teaching and learning of MSTs.

The ministry of education need to finalise the draft ICT education policy to guide and regulate the integration of ICTs in MSTs.

There is need to explore this subject further at a larger scale to be able to understand the general trends and the extent to which ICTs are integrated into the school system.

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Validating an instrument for use in assessing the technological literacy of upper secondary school students

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In this paper an instrument for assessing upper secondary school students’ levels of technological literacy is presented. The items making up the instrument emerged from a previous study that used a phenomenographic research approach to explore students’ conceptions of technological literacy in terms of their understanding of the nature of technology and their interaction with technological artefacts. The instrument was validated through administration to 969 students on completion of their 12 years of formal schooling. A factor analysis and Cronbach alpha reliability coefficient was conducted on the data and the results show that a four-dimension factor structure (namely, Artefact, Process, Direction/Instruction, and Tinkering) strongly supported the dimensions as developed during the original phenomenographic study. The Cronbach alpha reliability coefficient of each dimension was satisfactory. Based on these findings, the instrument has been shown to be valid and reliable and can be used with confidence.

Introduction
Technology education is typically enacted in schools through a subject referred to as Technology (Lewis, 1999). Many claim that the end-product of technology education is technological literacy (for example, Waetjen, 1993). However, there are numerous definitions of technological literacy. Some claim that the definition varies by discipline (Gagel, 1995 & 1997), while others (e.g., Garmire and Pearson, 2006) have argued that the definition can be confounded by socio-cultural context, where the social, cultural, educational and work backgrounds of individuals influence their understanding of technological literacy.

The uncertainty in definition implies that technological literacy is open to many interpretations. It is far from straightforward to assess student’s level of technological literacy - the outcome of technology education. An instrument to quantify a student’s level of technological literacy might give an indication of how effectively schools develop technological literacy in students and where improvements can be made. However, attempts to assess technological literacy using instruments of this nature have had limited success, primarily because instrument development is affected not only by the fact that technological literacy is a multi-dimensional term, but also that it is questionable whether a single instrument can be used for varying target populations, and importantly, that there is limited literature in the area to support claims.

Consequently, instruments currently available are largely influenced by the views and discipline of the authors. Our review of available instruments suggests that these provide disparate information, where one is unable to obtain a ‘full picture’ of what it means to be technologically literate. Garmire and Pearson (2006) have argued that one cannot administer a generic instrument as the ‘level of technological literacy’ changes to a particular group, for instance, to adolescents and adults. Nonetheless, a robust instrument to assess technological literacy is generally lacking. The work reported in this article presents the outcome of the development of such an instrument.

Theoretical framework
In a comprehensive analysis of technological literacy, Dakers (2006) highlights the critical need to engage young people in a new literacy – one in which they can navigate their way...
through a technologically-mediated world. He claims that students seldom have a discourse or literacy in this area, and thus have unreflective views and opinions about the advantages and disadvantages of technology. As a consequence many students reduce the concept of technology to raw materials – “stuff that we can transform into artefacts” (p. 2) – a view suggesting that humans control technology for our needs and wants. This way of conceptualising technology is simplistic and has to change to a more sophisticated level of thinking – through technology education (Dakers, 2006). Indeed, the role of technology education should be that of a roadmap to steer students’ thinking to evolve beyond their current basic understanding of technology as artefacts (computers, cars, televisions, toasters, genetically engineered tomatoes and so on); to a more sophisticated view that includes the awareness of knowledge and processes that create the artefacts, as well as the implications thereof (ITEA, 2000).

While Dakers (2006) provides a view of how students experience technological literacy, the expert – or considered – view of what it means to be technological literate is more nuanced and developed in its conception. Even though, as we suggested earlier, there is no single definition of technological literacy, recent work has begun to draw together some of the different views in a move toward unifying three of the major components or dimensions of technological literacy; a model which describes an individual’s level of technological literacy more holistically. The three-components are knowledge, capabilities, and critical thinking and decision-making (NRC, 1996; Garmire & Pearson, 2006). First, the knowledge dimension of technology literacy includes both factual knowledge and conceptual knowledge. Second, the capabilities dimension relates to how well a person can use technology (defined in the broadest sense) – and influences how a person solves problems during the design process. Lastly, the critical thinking dimension has to do with ones approach to technological issues. The three-part model is commensurate with a study of Collier-Reed (2006), who defined technological literacy broadly as ‘understanding the nature of technology, having a hands-on capability and capacity to interact with technological artefacts, and … be able to think critically about issues relating to technology’ (Collier-Reed, 2006, p. 15), a definition that has been adopted for this current work.

The challenge, though, is to quantify students’ levels of technological literacy. Boser et al. (1998) have argued that there is ‘no widely accepted standardized instrument suitable for assessing the broader construct of technological literacy’ (p.5). They claim that the ‘affective domain’ (cf. attitudinal studies such as PATT [Pupils’ Attitudes Toward Technology] (Raat & de Vries, 1985) is used ‘as an alternative way to assess technological literacy’ (p.5), often without satisfactory results. There have been various PATT (Raat & de Vries, 1985) conferences for which the proceedings provide a useful starting point. The PATT questionnaire is one of the best known technology-related instruments. In its early form, the questionnaire included a free-response, or essay, section that was meant to be assessed with reference to the ‘concept’ scales which were derived from literature as well as through interviews with professionals in the field – i.e., primarily reflecting the expert view of the dimensions. In the preliminary data analysis of the PATT-USA study, ‘none of the categories of responses to the essay question correlated with anything’ (Bame & Dugger Jr, 1989, p.315) in the ‘concept of technology’ scales. Once the 'concept' scales as such were shown by the PATT-USA study not to be useful, the expectation could have been that the essay section would be analysed differently for future uses of the PATT questionnaire. In fact, in a use of the PATT questionnaire in Hong Kong (Volk, Yip, & Lo, 2003), where a modified form of the PATT-USA questionnaire was used, the ‘concept’ questions were not included at all.

We suggest that the researchers recognised that what the students understood the concept of technology to be was not necessarily commensurate with how the experts agreed to define the
concept. In the modified questionnaire, the essay question remained, but interestingly, there appeared to be no mention of 'concepts' developing from it in the presentation of the results. With the ‘concept’ section omitted, there appeared to be no further attempt to analyse the qualitative data, only the quantitative data relating to pupils’ attitudes towards technology, was analysed. Our argument is that a large part of the reason why students could not distinguish the concept scales was that they were based on a review of technology literature and consultation with experts in the field of technology and technology education. As such, they did not necessarily represent the ways that students conceive of technology. A more useful approach could have been, in the first instance, to determine the ways in which students did conceive of technology and then develop the questions for the ‘concept’ section of the PATT questionnaire from that perspective.

Similarly, but focussed more specifically on technological literacy, a significant study that has investigated students’ levels of technological literacy was undertaken in 2001 by Saskatchewan Education in Canada. In this study, they looked to assess levels of technological literacy and provide ‘a snapshot of their [students’] skills, knowledge, attitudes and practices’ (Saskatchewan Education, 2001, p.1). For this investigation, they define technologically literate students as students that have the ability to ‘understand how technology and society influence one another and … [are able to] use this knowledge in their everyday decision making’ (p.1). One feature of the Saskatchewan Education data collection process is the assessment criteria against which levels of capacity and capability of the pupils were measured. These consisted of a set of levels developed by the ‘stakeholder representatives’ (Saskatchewan Education, 2001, p.62) that included various civil society and governmental organisations with educational as well as technical expertise. These are, as such, an ‘expert’ scale against which to judge levels of capability and capacity. However, there is no guarantee that students of this age will conceive of technology or interact with technological artefacts in terms of the levels developed by the stakeholders – a situation borne out by the nature of some of the results that emerged.

It is evident from these two studies that making use of expert views of what it means to be technologically literate in the development of dimensions for use in an instrument has the potential to be problematic. The results are influenced by students simply not understanding, or indeed recognising, some of the more advanced conceptions – dimensions – of technological literacy. What may have been more relevant, or useful, would have been to determine, from the students’ perspective, the range of ways that it was possible to conceive technological literacy and to base the dimensions used on this scale. This could then have been compared and contrasted with the scale determined by experts. We argue that this would give a better indication as to the actual technological literacy levels of students and not simply the levels based on what ‘experts’ expect.

Students’ conceptions of a phenomenon, in this case, technological literacy, can be described using phenomenography. Phenomenography is an empirical research tradition that was developed to answer questions about thinking and learning, especially in the educational context (Marton, 1986). Ways of conceiving a phenomenon have been shown in many studies of many different phenomena, to be limited in number with respect to a particular phenomenon (Trigwell, 2000). In other words, for any phenomenon, there are a limited number of qualitatively different ways that this phenomenon could be conceived and phenomenography describes the variation in conceptions of this phenomenon across a group of individuals; a collective (Dall’Alba et al., 1993; Trigwell, 2000). Phenomenographic research has as its outcome a set of categories of description that characterise the variation in the way a phenomenon may be conceived. This ‘complex’ of categories of description form what is referred to as an outcome space. The categories contain distinct groupings of descriptions of conceptions of a phenomenon. Central to an outcome space is that the
categories will be logically related. Once the outcome of a phenomenographic analysis has been finalised in terms of categories of description, an instrument could be developed where the dimensions – which would develop out of the categories of description – would then be reflective of students’ conception of that phenomenon. For example, Trigwell and Posser (2004) successfully developed an instrument, the *Approaches to Teaching Inventory* (ATI) using phenomenography to develop the dimensions utilised in the instrument.

Using the phenomenographic research approach, Collier-Reed (2006) conducted a study that explored students’ conceptions of technological literacy. These studies were conducted with the purpose of understanding how senior high school students in grades 11 and 12 conceive of and interact with technology; which he argued captured the key dimensions of what it was to be technologically literate. Drawing on the methodological approach described by Trigwell and Posser (2004), the outcome of this study (see for example Collier-Reed, 2006; Collier-Reed, Case & Linder, 2009 and Ingerman & Collier-Reed, 2011) informed the development of an instrument that could be used to assess a student’s level of technological literacy.

**Developing the instrument**

This study focusses on the refinement and validation of a widely-applicable and distinctive instrument for assessing students’ levels of technological literacy. The development and validation of the instrument has drawn extensively on prior work undertaken by the authors (Luckay & Collier-Reed, 2011 a & b). In earlier work, as described above, dimensions of technological literacy were developed (Collier-Reed, 2006) which, it was argued, collectively satisfied the core content requirements for what it means to be technologically literate. Using a phenomenographic analysis of interview data, five qualitatively different ways of conceiving the *nature of technology*, and four qualitatively different ways of conceiving *interacting with technological artefacts* (Collier-Reed, et al., 2009) were described. In order to classify students’ responses relative to these categories of description, a series of statements describing the dimensions of technological literacy were developed. In order to ensure congruence between the students’ responses and the categories, sections of an interview by such students relating to a specific category were ‘assigned’ to a dimension. These interviews were then reanalysed, finally resulting in a number of clearly defined statements (nominally in the students’ own words) pertaining to each category.

As an example of how a section from an interview was used in the development of a statement, consider the following extract that was classified as belonging to the category ‘Technology is conceived of as an artefact’:

> Well, it’s a bit complicated, firstly. It’s very technological. It’s exactly what I was talking about, what I said complicated wires and things that you don’t understand, it looked like technology. (Collier-Reed, 2006, p.123 – Italics in original)

From this interview extract, the following representative statement was constructed: *Things with complicated wires and parts that you don’t understand are technology*. Importantly, this process ensured that the statements derived from this process is the students’ own comments, and are thus in the style to which they can relate. Consequently, the pilot instrument was defined by 41 statements constructed in this way. There were 25 statements relating to experiencing the *nature of technology*, and 16 statements relating to the experience of *interacting with technological artefacts*. After refinement of the original instrument, where the focus was also on clarity and readability of items, the revised instrument remained valid and reliable (Luckay & Collier-Reed, 2011a&b) – with data being collected from 1064 students across two pilots.

During the first pilot (Luckay & Collier-Reed, 2011a), the instrument was administered to 435 students early in their first year of study at the University of Cape Town. The groups were split between engineering (198) and commerce (237) students. Exploratory factor
analysis supported the existence of six dimensions, offering notational support for the distinctions between artefact, process, direction, instruction, tinkering and engagement. These findings were used to refine the item pool for clarity. Items that showed factor loadings less than 0.3 were deleted from further analyses. The result was a 23-item survey, which was adjusted to a 30-item survey after some of the items were re-considered by the authors to ensure that the items fit the dimension for conceptual clarity.

Two additional pilots were conducted in order to further clarify the dimensions. In Pilot 2, the 30 item survey was administered to 629 high school and first-year university students. The group was diverse consisting of students at the end of high school and those entering their first year of university, but all in the same age range from 17 to 18 years old. Additionally, the students at university were from diverse faculties, namely, engineering, commerce and arts. Exploratory factor analysis suggested that a five rather than a six dimensional solution was more interpretable in terms of the factors formed (Luckay & Collier-Reed, 2011b). The Direction and Instruction scales came together during the factor analysis, suggesting that students regarded Direction and Instruction in similar ways. This suggested that Direction and Instruction should be combined, and that a new combined scale should be formed. Moreover, the factor analysis suggested a new 27-item survey be formed, with three items being discarded as their loadings were less than 0.3. However, the researchers elected to retain the three items as it provided better conceptual clarity, and thus a 30-item survey was retained.

The resultant 30-item instrument was used in the present study. Data were collected from 969 students within their first three weeks of study at the University of Cape Town. The sample was drawn from the Engineering and the Built Environment (312), Health Sciences (80), Science (289) and Humanities (288) faculties. Participants were required to supply biographical information including their age, gender, current degree programme, and high school attended. From this information, it was determined that the sample consisted of 480 (50.3%) males and 475 (49.7%) females – 14 of them did not indicate their gender. The average age of the students was 19 years (SD = 2.28) – 24 students did not indicate their age.

The instrument was administered by the authors to ensure consistency in the instructions given to the students and to answer possible queries. Participants were required to mark on a seven-point Likert scale (Cohen, Manion, & Morrison, 2000) their level of agreement with each item on a scale ranging from Strongly Disagree to Strongly Agree. The data collected from the students were used to examine the validity and reliability of the instrument. As a first step, a factor analysis was performed to cluster variables (Field, 2005). The sample size for the present study was appropriate to perform such an analysis as Tabachnick & Fiddell (2007) suggest that ‘it is comforting to have at least 300 cases’ (p. 613). Additionally, Nunnally (1978) recommends that the ratio of the items to subjects is ten to one, that is, 10 cases for each item to be factor analysed. Others have suggested 5 cases for each item (Tabachnick and Fiddell, 2007). The data collected thus meet the requirements for both sample size and case to item ratio.

Results
Validity and reliability
The data were collected from 969 students across four faculties at the University of Cape Town and used to examine the validity and reliability of the instrument by performing a principal component factor analysis followed by a varimax rotation.

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<thead>
<tr>
<th>Item No.</th>
<th>Artefact</th>
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395
During this analysis, careful attention was given to the dimension *Engaging* as it manifested itself in the data. In the original phenomenographic analysis from which this dimension developed, engaging with a technological artefact was described as taking ‘place in the context of self-initiated free enquiry with prior experience being drawn from, and supplemented as required, to inform the interaction’ (Collier-Reed, 2006, p.101). The original study suggests that this dimension is not strongly experienced by students of this age – and is an advanced conception; a view supported by an analysis of the current data. Removing the questions associated with this factor in a five factor solution resulted in a more robust and reliable four factor solution as presented in Table 1. The impact of this decision will be discussed below.

Overall, the percentage variance accounted for by the different scales ranged from 4.84% to 18.30%, with a total variance accounted for being 42.03%. Table 1 shows that the eigenvalues ranged between 1.26 and 4.76 for the four dimensions. For the revised instrument, the Cronbach alpha co-efficient was used as an index of scale internal consistency. A careful analysis of the factor loadings as well as the Cronbach alpha co-efficients of the *Tinkering* factor indicated that it would be appropriate to omit Item 06 from the instrument. Table 2 shows that the internal reliability (Cronbach alpha co-efficient) ranged between 0.63 and 0.84. Overall, these results indicate that the internal consistency for the instrument is satisfactory (Field, 2005; Kline, 1999).

**Table 2.** Cronbach alpha coefficient for the modified version of the instrument

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<td>0.64</td>
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<th>% Variance</th>
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<th>18.30</th>
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<td>Scale</td>
<td>No. of Items</td>
<td>Cronbach alpha coefficient</td>
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<td>Artefact</td>
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<td>Tinkering</td>
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Taken together, the results for the factor analysis, as well as the index of scale reliability (Cronbach alpha reliability index), suggest that the instrument is reliable and valid to use for upper secondary school and first year university students. The final version of the instrument consists of 25 items and is presented in Appendix 1.

**Discussion and concluding remarks**

The development and validation of the instrument – to determine students’ levels of technological literacy – is timely given the renewed focus internationally on the importance of developing a technologically literate youth (Ingerman & Collier-Reed, 2011). The instrument was rigorously developed, captures the important dimensions of technological literacy, and provides educators and researchers with an accessible means of determining students’ levels of technological literacy. The factor structure for the instrument shows congruence with the nature of the categories that emerged from the original phenomenographic analysis. All items have a factor loading of at least 0.35 on their *a priori* scale and no other scale. Furthermore, the internal consistency reliability estimate (Cronbach alpha coefficient) for each of the dimensions of the instrument, was comparable with past studies (ibid).

The authors’ previous work (Luckay & Collier-Reed, 2011a&b) has described how the original dimensions that emerged from the phenomenographic study are currently represented in the factors. These factors usefully straddle the product / process divide with respect to the nature of technology on the one hand and students who shy away from interacting with technological artefacts versus those who are uninhibited in their interaction with these artefacts through tinkering on the other.

For the scale *Direction/Instruction*, in Pilot 1 (Luckay & Collier-Reed, 2011a), the results suggested that the scale *Instruction* was less useful as a stand-alone scale. However, in Pilot 2 (Luckay & Collier-Reed, 2011b), and in the present study, the reliability co-efficient suggest that combining the scales *Direction/Instruction* was more meaningful (the Cronbach alpha reliability was 0.83) (Table 2). Interestingly, the fact that the two scales merged in the factor analysis (Table 1) suggest that the students could not distinguish between the teacher was directing them or instructing them. Students see *Direction* described by Collier-Reed (2006) as:

The result of a directive by someone. It is not something that happens spontaneously as there is reluctance to making the first move toward approaching it. This category describes the experience as being on the outside looking in towards a technological artefact as a reified object, the artefact is placed on a ‘pedestal’ in an exalted, unapproachable position. (p. 298)

Collier-Reed described *Instruction* as ‘receiving instruction via some means which enables the interaction with the artefact’ (p. 299). Thus, it could be that students preferred being helped or guided to ways of initiating their interaction with a technological artefact. It is likely that these students lacked the spontaneity to interact with a technological artefact independently. The results from this study could have implications for both professional development programs for teachers and classroom practices in South Africa. This instrument provides an important means of monitoring their teaching – particularly in cases where there is a blurring between directing and instructing students. Here, teachers might adjust their
learning environment towards a more focused promotion of a technologically literate environment.

For the scale *Tinkering*, the scale plays an important role in distinguishing groups. This scale is described by Collier-Reed (2006) as:

characterised by a self-initiating interaction with a technological artefact by beginning to tinker with it...[T]here is no need for instruction to enable the interaction. There is no sense of being intimidated by anything to do with the artefact...[They] recognise that an artefact has a variety of functions and set out to determine what they are and make the artefact operate (ibid, p. 299-300).

The fact that students are able to self-initiate their interaction with a technological artefact implies that these students have moved beyond being directed or instructed to interact with an artefact. They most likely have the skill, ability and understanding to interact with an artefact in a more sophisticated way. Thus, it could imply that whatever level of academic development, some students have an innate ability to interact with a technological artefact, without being initiated by some form of direction or instruction from an outside source. Students who have the ability to self-initiate through tinkering might have be better candidates for technical programmes, like Engineering. In fact, comparing the technological literacy of students across faculties, Luckay & Collier-Reed (2011b) found that Engineering and Science Exposition students are more likely to tinker than Arts or Commerce students, however further research is required, as the questionnaire could ultimately be used as a tool to select students for technical programmes like Engineering.

Based on these findings, the instrument has been shown to be valid and reliable and can be used with confidence in future research.

**References**


**Acknowledgements**

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Appendix 1: TPI Items
Technology is a person making something to solve a problem and improve quality of life.
I would rather play around with a technological thing than waste time first reading instructions about how to do it.
A CD is only technology when you put the CD into a computer and then copy music onto it. It is fun figuring out how technological things work without being given instructions to follow.
When I see a new technological thing, the first thing I want to do is play around with it to see what it can do.
I like opening up technological things to see what’s inside.
Technology is an idea that has been put into place by someone to help people.
Technology is about using scientific knowledge to make something.
I would rather get someone else to work a technological thing. I might get it wrong or mess it up.
Only with instructions, I would be able to find how to do what I want with a technological thing.
Technology is all about computers and other electronic and electrical things like that.
Technology is making use of knowledge people have about something and using this to solve a problem.
Only if someone first shows me how to do something with a technological thing, then I can use it.
When using technological things, instructions tell me exactly what to do – and only then I can do it.
Technology is using knowledge and skill to develop some product.
I would rather watch someone work with a complicated technological thing instead of trying to do it myself.
Things with complicated wires and parts that you don’t understand are technology.
Something is technology because a person had a plan that was put into practice by making it.
I always seem to do something wrong when I try to use technological things.
A television is technology only when you watch a movie on it using signals from the air.
Technology is about solving a problem.
An amplifier or CD player becomes technology when it is switched on.
Technology is the planning and research of something and then the making of it.
A washing machine thrown on a rubbish dump with no motor or wires is no longer technology. It is just a thing.
The status of technological literacy and awareness among learners

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Abstract
The economic development in the world dependent on the technological literacy of every citizen. This refers to the knowledge, skills, and usage of technology for survival by making ones life better and improving human life. This study investigated the level of technological literacy among learners of grades 8-12 from schools in Soshanguve and Garankuwa. The participants were 90 learners selected conveniently during National Science Week. Learners completed questionnaires responding to biographical information and variables measuring aspects of technological literacy. The data was analysed using SPSS software to obtain frequency distribution and statistical correlation between biographical data and aspects of technological literacy. The study found that majority of learners in grade 11 have a considerable idea about technology. The study found that there is no significant difference between girl learners and boy learners with regard to the awareness of technology. However, there is much to be done promote technological literacy at schools for all learners across the gender.

Introduction
Technology played an important role in our country as it is one of the developing countries. Technology is a human activity that aim to develop solutions to people’s needs using knowledge, skills, value and resources through investigation, design, make, evaluate and communication while taking social and environmental factors into consideration (Department of Education, 2004). This definition concur with most of the international statements which provide students with opportunities to participate actively in learning environment and could draw upon their existing knowledge of materials, tools, machines, and systems, as well as gather and search information from a variety of sources (Makgato, 2011). For example, in Australia they define technology as an application of knowledge, skills, experience and resources to create products and processes that meet human needs (Curriculum Corporation, 1994). In educational context, technology can be defined as “the use of knowledge, skills, values and resources to meet people’s needs and wants by developing practical solutions to problems, taking social and environmental factors into consideration” (Department of Basic Education, (DBE) 2011). Technology brings the ability to incorporate multiple literacies within curriculum (Kalu, 2005).

Technology Education Act of 1986, recognizes that our future prosperity depends on our students’ ability to compete in an increasingly technological world (DBE, 2001). To meet these challenges, Technology education would help develop a technologically literate population through instructional programs in schools. Technology education was introduced into the new South African curriculum in 1998 (Ankiewicz 2003). Technology subject was designed to introduce learners and arouse their interest in the field of engineers, technicians and artisans in order to close the gap in terms of skills (DBE, 2011). The main aim was to produce technologically literate population in order to meet the need in modern society as well as modern world (Makgato and Gumbo, 2008). Technology education as a subject was designed in such a way that it must contributes towards learners” technological literacy by giving them opportunities to develop and apply specific design skills to solve technological problems; understand the concepts and knowledge used in Technology education and use them responsibly and purposefully; and appreciate the interaction between people’s values
and attitudes, technology, society and the environment (DBE, 2011). In addition, the subject stimulates learners to be innovative and develops their creative and critical thinking skills. It teaches them to manage time and material resources effectively, provides opportunities for collaborative learning and nurtures teamwork (ibid).

Therefore, the learners who participated in this study where ranging between grade 8 to grade 12. According to the time frame since the new curriculum has been introduced, the assumption is that all these learners were exposed to the content of technology as a subject. Therefore, the purpose of this paper is to explore the level of awareness that learners have towards technology.

**Gender sensitivity**
Female are largely an untapped creative resources in technology and or/engineering fields. In South Africa female are underrepresented in the field of technology and engineering. Similar challenge has been experience in Nigeria where girls are under-represented in physical education and they achieve lower compared to boys (Kalu, 2005) and Olagunju, 2001). Some of the factors that inhibit and discourage females students to learn Science, Technology and Mathematics education are lack of influence from female role model, curriculum designers, school expectation (Kalu, 2005), teachers interacting with male than female (Ballamy, 1994). Kalu (2005) conducted a study of ‘classroom interaction behavior in physics lessons, relative to students sex’ and found that teachers interaction with students depend on two behavior categories. Firstly, teacher favour girls over the boys on the aspects of verbal rewards of social behaviours, criticism of social-orientated behaviours and students questions. Lastly, teachers favour boys over girls on the aspects of reinforcement of responses, criticism of content-specific behaviours and supervision of work. However, in countries like Europe this trend cannot be acceptable as it doesn’t apply to their context (Kelly, 1976). Therefore, to what extend do this phenomenon occur in technology education?

**Importance of technology**
Technology plays a crucial role in the teaching and learning of curriculum. The use of technology help teachers to presented information in multiple ways e.g. verbal information and visual information (Smolin & Lawless, 2003). Technology enable teacher to use presentation software to present lesson to a bigger class without disadvantaging those who are at the back. Technology enabled the teacher and student to use of variety of resources to retrieve information easily and quicker which is required in this paradigm shift (Smolin & Lawless, 2003). For example, teachers and students can use their cell phones to get internet or other devices to retrieve information without going to the library or controlled by linear text for mats. Teachers can also use technology to communicate with their students while teaching using clicker or other electronic device. Students can form groups of learning and communicate using facebook, twitter and other communication device to learn by asking each other questions and responding without face-to-face communication.

**Technological literacy**
The concept of “technology literacy” plays a central role in the educational reform, especially in the South African context. Most of the studies assume that the challenge of defining the term ‘technology’ was entrenched in a lack of understanding technology than literacy (Lewis & Gagel, 1992). However, in a later stage, it was discovered that the understanding of both technology and literacy depend on each other and are of ongoing debate (ibid). South African Department of Basic Education (2011) defined technological literacy as the ability to “develop and apply specific design skills to solve technological problems; understand the
concepts and knowledge used in Technology education and use them responsibly and purposefully; and appreciate the interaction between people’s values and attitudes, technology, society and the environment’. United State of America Department of Education is defined technological literacy as "the ability to use computers and other technology to improve learning, productivity and performance" (Frantz, Friedenberg, Gregson, A. & Watter, 1996). They further explain that to be technological literate is to know how to use technology in conjunction with school subjects to increase academic performance. Smolin & Lawless (2003) explain technologically literate person as someone who understands what technology is, how to use it and can use it comfortably.

Smolin and Lawless (2003) conducted a study on ‘coming literate in the new technological age: new responsibility and tools for teachers. The authors identify the new literacies of this technology age and explore a variety of tools available to teachers. The study investigates two cases of language teachers and found that both teachers use multiple resources like computer, audiotape, video camera and digital camera to reshape their curricula. Students use those varieties of technologies as they are learning how to work in groups, how to express their ideas, and how to communicate. These methods enhance students’ abilities to understand and use multiple technologies in order to acquire, evaluate, and organize information. The resources described in this article enable students to move beyond operational skills to learn how to harness these powerful tools effectively in order to be technological literate. However, students don’t learn these technology skills in isolation but are waved in the context of a curriculum aimed to develop their literacy. Through this contextual approach of learning how to use technologies students are developing technological literacy. Therefore, based on the school and social experience that the learners have acquired throughout their school, what do they understand by technology?

Information and visual literacy
In today's world, we are bombarded with information which requires a person to know when, where and why you need information. Information literacy is the ability to find, evaluate, analyze, and synthesize information within a specific context (Smolin and Lawless, 2003). A teacher must help his or her students develop their abilities to use information to construct knowledge (ibid). Information literacy is defined as the ability to relate to digital literacy, media literacy, information fluency and academic research skills (Lewis & Gagel, 1992). The curriculum of South African in line with most of the literature as it ‘aims to produce learners that are able to communicate effectively using visual, symbolic and/or language skills in various modes’ (DBE, 2011).

Finson & Pederson (2011) defined visual literacy as the ability to understand and produce visual messages. Children acquire information and develop language through multiple skills (Smolin and Lawless, 2003). In order to be literate in this technological age, students must learn to make meaning not only out of text but also out of the vast amount of visual information conveyed to them through images (ibid). A visually literate child can examine, extract meaning and interpret the visual actions, objects, and symbols that he/she encounters in the environment (Finson & Pederson 2011). Smolin and Lawless (2003) argue that to develop a learner to be visually literate the teacher must help him/her to use these abilities to communicate with others. Referring to the study of Smolin and Lawless (2003) discussed above, they also found that most of the learners develop an understanding of "bilingualism" through a variety of sources, which include text and images. For example, learners used digital pictures to conduct interviews data and after that they discussed what they have learned from their interviews (ibid). They then arrange these pictures and, along with text,
communicate this newly acquired knowledge to members of the school community. Therefore, it is very imperative for teachers to use visual, sense, touch, smell, and hearing literacy when preparing lesson so that it can help learners to be technological literate.

**Technology design**
Design is a production of plan or drawing that show the appearance and function of an object before it is made for example building, garments etc. Design is the human activity’s which include experience, knowledge and skills with ability to build or mould his environment and solve human’s problem with the use of resources. Department of Education (2004) develops a policy that introduce and forester the skill of product design and production in Technology Education. It is expected that Technology education will provide learners with some experience to help them to make career-oriented in the FET subjects (ibid). In technology education design is often refer to as design process or technological process. Design process is about identifying needs, generating ideas, planning and creating, testing and finding the best solution (Makgato and Gumbo, 2008). Design process as the fulfillment of the end product or satisfaction of the need. The concept of design includes design solution to the problem which can be seen as a new paradigm for education (Makgato and Gumbo, 2008). Therefore how do learners understand the word design?

**Technology, innovation and entrepreneurship**
Technology is the application of knowledge that deals with creating and use of resources in relation with life, society and the environment. Technology is most used in the market of business and education today in order to promote product and learn (Kalu, 2005). Most of the technology like computers, smart devices like cell phones, ipad etc are the most used devices (ibid). The enterprise hardware market has expanded from traditional enterprise to technological enterprise for example from desk PCs and servers to business laptops and tablets, printers, consumables and audio visual devices. Technology can be used as a tool in order to be Innovative (Goodman, 2000). Innovation can be taught and learned to achieve a specific desired outcome using different methods. In this world of competition, transformation, and change innovation can be viewed as essential not a luxury (Powell and Brantley, 1992).

Sustainable innovation is an emerging and fundamental force for change in business and society (Larson, 2000:1). Innovation can be viewed as an area of entrepreneurial opportunity and a force of creative exercise to transform technology, products and markets (ibid). It can help you to get people to work in new ways or to create new products (ibid). Powell and Brantley (1992) explain innovation as the creation of better or more effective products, process, services, technology or ideas that are new. It is vital for all businesses need to innovate, however it may take any number of stages to establishment product and launch an idea (ibid). Innovation is the specific instrument of entrepreneurship (Li & Atuahene-Gima, 2001). Entrepreneur is someone who builds or starts a business through risk (ibid). The future of many businesses depends upon their ability to innovate (Kalu, 2005). However, there are other environmental factors that can hinder the success of product innovation. Li & Atuahene-Gima (2001:1124) argue that the effectiveness of product innovation strategies of new technology ventures depends on:

- Managerial perceptions of the peculiarities of the transitional economic environment;
- Complex environmental situations than their counterparts in market economies;
- Government, legal, and financial institutions;
- Environmental management;
Support received from government institutions to alleviate their resource and managerial problems;
Dysfunctional competition behavior of competitor in a market;
Unlawful behavior such as patent and copyright violations, broken contracts and agreements, and unfair competitive practices;
The intellectual property rights of new technology ventures which resulting from product innovation which can go unprotected;
Making product innovation a highly risky and less profitable strategy.

These are challenges and they open a gap between discovery of new technology and their development into industry (Li & Atuahene-Gima, 2001). This gap needs to be bridge in order to create commercial proposition that can attract venture capital investment (ibid). Therefore, to what extent to learners understand the word innovation and entrepreneurship?

**Theoretical framework**
This study used the notion of ‘genre of technology’ which was adapted from (Seemann, 2003). Seemann used the genre technology and identify two components that explain this notion i.e. ‘know how’ and ‘know why’. This notion helped him to investigate how teachers understand and teach different elements of technology. In addition, it was also used to reveal the utility of such understanding when making technical choices, design decisions, application, discovery and transferring technological knowledge. Paling (2004) conducted a study on ‘technology, value and genre change’ and evaluate two case of small literacy magazines. Paling adapted the notion of ‘genre of technology’ from (Seemann, 2004), and use the element of ‘know what’ and ‘know where’. In the study he found that the literacy magazine editors who publish their magazine online get more respond than those who publish their magazine on paper. Based on this findings he developed another notion of ‘creative genre’. As stated earlier, this paper adapt the notion of ‘genre of technology’. The paper used the element of ‘know what’ and ‘know where’ in order to examine learner’s awareness of technology in the new technology age. Therefore, the focus will be on evaluating their knowledge of what is and where technology can be applicable in a real-life context.

**Methodology**
Convenience sample of 90 learners who where participants of National Science Week was used in the study. The participants were learners from grades 8-12, consisting of 53 females and 37 males. The learners were from schools in Soshanguve and Garankua locations. Data was collected using questionnaires containing biographical data and specific variables/statements measuring awareness and technological literacy in learners. The data was analysed using SPSS software reporting on frequency distribution on variables of technological literacy measured and correlation between biographical data (gender) and some variables measuring technological literacy.

**Results and discussions**

**Table 1. Learners grades**

<table>
<thead>
<tr>
<th>Learners school grade</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 8</td>
<td>5</td>
<td>5.6</td>
<td>5.6</td>
<td>5.6</td>
</tr>
<tr>
<td>Valid Grade 9</td>
<td>3</td>
<td>3.3</td>
<td>3.3</td>
<td>8.9</td>
</tr>
<tr>
<td>Grade 10</td>
<td>8</td>
<td>8.9</td>
<td>8.9</td>
<td>17.8</td>
</tr>
</tbody>
</table>
Table 1 illustrate the school grade of learners who participated in the study. Majority (71.1\%) of learners were from grade 11, while only few (11.1\%) were from grade 12 classes. These frequency distribution of learners across the grades merely indicate learners who participated during the Science Week. There were very learners from other grades as Table 1 illustrate.

Table 2. Learners’ genders

<table>
<thead>
<tr>
<th>Gender</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>53</td>
<td>58.9</td>
<td>58.9</td>
<td>58.9</td>
</tr>
<tr>
<td>Male</td>
<td>37</td>
<td>41.1</td>
<td>41.1</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>90</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

The biographical data of gender distribution of learners is shown in Table 2. Majority (58.9\%) of learners were females, while 41.1\% were males. This gender distribution nearly comply with government requirements of gender distribution according to the demographic majority of population. There has been a great shift in most schools about having majority of girl learners at schools since the democratic dispensation in the country. There are also several initiative which promote girl learner participation in technological field of studies. Powell and Frankenstein (1997) argues that when particular gender groups outnumbers others, the majority groups tend to defer the minority gender groups. Powell found that balanced gender groups with equal number of boy learners and girl learners provide the best opportunity for equal participation.

Table 3: Knowledge and awareness of technology

<table>
<thead>
<tr>
<th>Technology</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computers</td>
<td>38</td>
<td>42.2</td>
<td>42.2</td>
<td>42.2</td>
</tr>
<tr>
<td>Internet</td>
<td>3</td>
<td>3.3</td>
<td>3.3</td>
<td>45.6</td>
</tr>
<tr>
<td>Cars</td>
<td>2</td>
<td>2.2</td>
<td>2.2</td>
<td>47.8</td>
</tr>
<tr>
<td>Education</td>
<td>12</td>
<td>13.3</td>
<td>13.3</td>
<td>61.1</td>
</tr>
<tr>
<td>Cellphone/mobile</td>
<td>3</td>
<td>3.3</td>
<td>3.3</td>
<td>64.4</td>
</tr>
<tr>
<td>Science</td>
<td>32</td>
<td>35.6</td>
<td>35.6</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>90</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Learners were asked to respond by ticking relevant items listed on Table 3 which they think is associated with the word ‘technology’. Table 3 shows that most (42.2\%) of learners referred to ‘computers’ as technology, followed by 35.5\% who stated that ‘technology’ is ‘science’. According Gumbo and Makgato (2008) has had varying interpretations over the years due to general confusion. The word ‘technology’ has been equated with machinery such as computers, cars, scissors, and the list goes on. This understanding has its origin in various advertisements in newspapers and TV (ibid). Similarly for learners who chose ‘technology’
as ‘science’ is not very surprising in that it has been found that the two concepts are not very different (Gumbo and Makgato, 2008; Maluleka, 2000). Based on these findings it can be interpreted that these learners have degree of technological literacy (Luckay and Collier-Reed, 2012). Few learners (13.3%) mentioned that the word ‘technology’ is education which could be viewed as lack of awareness of what technology is. These understanding could be from learners in lower grades such as 8, 9 and to some extend grade.  

Table 4. Knowledge/ awareness of technology and gender

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Count</td>
<td>21</td>
<td>17</td>
</tr>
<tr>
<td>% within Gender</td>
<td>39.6%</td>
<td>45.9%</td>
</tr>
<tr>
<td>Count</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>% within Gender</td>
<td>1.9%</td>
<td>5.4%</td>
</tr>
<tr>
<td>Count</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>% within Gender</td>
<td>0.0%</td>
<td>5.4%</td>
</tr>
<tr>
<td>Count</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>% within Gender</td>
<td>13.2%</td>
<td>13.5%</td>
</tr>
<tr>
<td>Count</td>
<td>22</td>
<td>10</td>
</tr>
<tr>
<td>% within Gender</td>
<td>41.5%</td>
<td>27.0%</td>
</tr>
<tr>
<td>Count</td>
<td>53</td>
<td>37</td>
</tr>
<tr>
<td>% within Gender</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Statistical cross-tab test was done to view the relationship between gender and the choice of technologies. From 4 it appears that majority (45%) of male learners chose computers when they heard the word ‘technology’ as compared to 39.6% female learners. However, majority (41.5%) of female learners chose science as ‘technology’ as compared to 27% of male learners. Contrary to the general believe that girl learner are under-represented in the field of science and technologies (Kalu, 2005 and Olagunju, 2001), this findings does not show girl learners are seriously lacking awareness in aspects of technologies. In this table, it is shown that girl learners are competing better with boy learners. Further, there are several initiative interventions to balance the gap between boys and girls representation in the field of SET(Science, Engineering and Technology) in most provinces in South Africa (Makgato and Mji, 2006). Nearly equal number of boys (13.5%) and girls (13.2%) indicated that the word ‘technology’ refers to education, which indicated some confusion as what technology is among some considerable number of learners.
Conclusion
The paper reported on the quantitative findings of the study that investigated the awareness and technological awareness of learners within some schools in Soshanguve and Garankuwa around Pretoria. Given the importance of technological literacy globally, the study shares some light in understanding learners technological literacy, particularly at higher such as grade 10 -12. The study found that majority of learners in grade 11 have a considerable idea about technology. However, the study cannot that learners have advanced technological literacy due the limitations of not getting deep in aspect of technology. The study found that there is no significant difference between girl learners and boy learners with regard to the awareness of technology. However, there is much to be done promote technological literacy at schools for all learners across the gender.

References
Challenges facing FET teachers in the implementation of technology in the further education and training band in North West

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Abstract

The change in the political climate in South Africa brought with it inevitable curriculum reform and Technology emerged as a new subject in the Further Education and Training (FET) Band. The newness of Technology and the new pedagogy of the curriculum reform created more challenges for this subject than any other subject (Makgato, 2003a: 18). The implementation of Technology has been surrounded by problems of a different nature (Department of Education, 2000: 11) hence; its implementation was carried out under a cloud of misconception regarding the nature of such a subject and its value to the school curriculum (Du Plessis & Traebert, 1995: 68). The purpose of this study was to identify and evaluate the challenges experienced by Technology teachers in the Further Education and Training (FET) Band and to suggest the mechanisms that can be used to address these challenges. Both qualitative and quantitative methods were used in this study. The study involved all Further Education and Training Band teachers offering Technology in 12 high schools. The number consisted of 60 teachers teaching Technology, 12 heads of Department for Technology and six (6) Subject Advisors for Technology based at the district office. The total population was 78. The findings of this study revealed that very few teachers had received formal training in the teaching and assessment of Technology. Lack of qualifications or little knowledge in the subject compromised the quality implementation of the subject due to minimal conceptual knowledge that goes with lack of appropriate qualification.

Introduction

In the past Technology was taught as vocational studies. Learners were directly prepared for a job, for example as electricians, carpenters, welders or blacksmith among others. Technology was taught as electricity, woodwork and metalwork among others (Ankiewicz, 1995: 6). Presently Technology acquired at the school level i.e. Mechanical Engineering, Electrical Engineering, Civil Engineering, Graphics and Design Information Technology and Food Technology lays the foundation for advanced technological and engineering fields at university level. (Department of Education, 2003: 9).

In the Further Education and Training (FET) Band, Technology subjects i.e. Civil Technology is inclusive of brick laying, carpentry and plumbing; Mechanical Technology is inclusive of welding and metal work, fitting and turning as well as motor mechanics; Electrical Technology is inclusive of Electronics and Electrician’s work; Engineering Graphics and Design is inclusive of technical drawing, engineering drawing and Information Technology replaced technical education (Department of Education, 2004: 15). These are hereafter referred to as Manufacturing, Engineering and Technology subjects. These subjects are not differentiated into different grades but are organized to cater for learners with different abilities and talents (Makgato, 2003b, on line).

According to Ankiewicz (1995: 9) problems arise if Technology in schools is misused for the purpose of pure vocational education. He argues that the subject, Technology should be perceived as more than the artificial merging of the above-mentioned subjects. It is not only a subject in which certain skills are being taught to prepare learners for the world of work, it should be a general formative subject that ought to contribute to the education of the learner
in totality. Tholo (2007: 9) indicates that Technology is offered as a compulsory subject in the General Education and Training (GET) Band. In the FET Band it is offered as a specialized subject.

Theoretical underpinnings
Constructivist teaching is based on the belief that learning occurs as learners are actively involved in a process of meaning and knowledge construction as opposed to passively receiving information. Learners are the makers of meaning and knowledge. Constructivist teaching fosters critical thinking, and creates motivated and independent learners (Wikipedia, 2012: 1)

This study is underpinned by Constructivist theorists such as Piaget, Dewey and Jonassen who believes that Constructivist teaching methods are based on the constructivist learning theory. According to Paiget (2010, para. 2) the role in the constructivist teaching suggests that we learn by expanding our knowledge by experiences which are generated through play from infancy to adulthood which are necessary for learning. Dewey (2010, para .2) suggests that education must engage with and enlarge experience and the exploration of thinking and reflection associated with the role of teachers. According to David Jonassen (1999), in constructivist learning environments learning is driven by the problem to be solved; learners learn content and theory in order to solve the problem.

Constructivist learning environment
Jonassen (1999) identified three major roles for teachers to support learners in the constructivist learning environment that is modelling, coaching and scaffolding.

Modelling is described as the most commonly used instructional strategy in constructivist learning environment. There are two types of modelling that is behavioural modelling for the overt performance and cognitive modelling of the covert cognitive processes. Behavioural modelling in constructivist learning environment demonstrates how to perform the activities identified in the activity structure. Cognitive modelling articulates the reasoning that is reflection-in-action that learners should use while engaged in the activities.

Furthermore, Jonassen (1999) acknowledges that a good coach motivates learners, analyse their performance, provides feedback and advice on the performance and how to learn about how to perform, and provokes reflection and articulation of what was learned. In addition, coaching naturally and necessarily involves responses that are situated in the learners’ task performance (Laffey, Tupper, Musser and Wedman, 1997)

Scaffolding is a more systemic approach to supporting the learner, focusing on the task, the environment, the teacher and the learners. Furthermore, scaffolding provides temporary frameworks to support learning and learner performance beyond their capacities. Wood and Middleton (1975) suggest that the concept of scaffolding represents any kind of support for cognitive activity that is provided by an adult i.e. a teacher when the child i.e. a learner and adult are performing the task together.

Jonassen has proposed a model for developing constructivist learning environment around a specific learning goal. This goal may take one of several forms, from least to most complex that is questioning, case study, long-term project and multiple cases and projects integrated at the curriculum level.
**Role of teachers in a constructivist learning environment**

According to Dewey (2010, para.4) teachers are the organs through which learners are brought into effective connection with the material, they must be recognised as understanding of the needs of their followers, they must have some plans for their learners’ success and must earn this role. In relation to experience-based learning, it is the role of teachers to facilitate proper experiences for their learners. Teachers must not only design the environment to create experiences but also be keenly aware of what direction an experience is heading in, hence learners should be provided with the opportunity to interact with the sensory data and construct their own world. Parker J.P. (1979) suggests that good teachers join self, subject, and learners in the fabric of life as they teach from an integral and undivided self, they manifest in their own lives, and evoke in their learners a capacity for connectedness.

**Constructivist assessment**

In constructivist teaching the process of gaining knowledge is viewed as being just as important as the product. Thus, assessment is based not only on tests but also on observation of learners’ work and points of view.

Jonassen (1999) suggested the following constructivist assessment strategies:

- **Oral discussion:** The teacher presents learners with a focus question and allows an open discussion on the topic.
- **KWLH Chart:** That is what we **K**now, what we **W**ant to know, what we **L**earned and **H**ow we know it. This technique can be used throughout the course of study for a particular topic, but is also a good assessment technique as it shows the teacher the progress of the learners throughout the course of study.
- **Mind Mapping:** Learners list and categorise the concepts and ideas relating to a topic.
- **Hands-on activities:** This encourages learners to manipulate their environments or a particular learning tool. Teachers can use a checklist or rubric and observation to assess learner’s success with the particular material.
- **Pre-testing:** This allows a teacher to determine what knowledge student bring to a new topic and thus will be helpful in directing the course of study.

**Significance of the study**

This study intended to contribute to a better understanding of the situation facing Technology teachers. The study also intended to inform the government on the level of preparedness of teachers in the implementation of Technology as a new subject. The study, furthermore, intended to make the Department of Education aware of the corrective measures that can be put in place in the successful implementation of Technology. Subject advisors for Technology, and principals, may also use the findings of this study to provide support that would assist teachers in the teaching and learning of Technology. Makgato (2003: 423b, on line) stresses the notion that the new Technology subjects for FET schools have broadened access to Technology to the majority of learners. The cost of developing appropriate learning support materials, providing qualified teachers and examining the subject is huge. Three Technology subjects i.e. Manufacturing, Engineering and Technology, should build knowledge and skills so as to exploit natural resources to contribute to South Africa’s socio-economic and politico-cultural development. This includes the promotion of health education, sustainable management of the environment, technological advancement, mining, housing, rural development and urban renewal. Meeting these demands requires a high level of skills and knowledge in Technology teachers.
Purpose of the study
The purpose of this study was to identify and evaluate the challenges experienced by teachers in the process of implementing Technology as a new subject in the Further Education and Training (FET) Band. A further aim of the study was to identify the difficulties that teachers encounter during the implementation of Technology and to suggest the mechanisms that can be used to address these challenges.

Research questions
The study was guided by the following research questions:

What challenges are experienced by teachers in the process of implementing Technology as a new subject?
What is the level of preparation of teachers for the implementation of Technology in the Further Education and Training (FET) Band?
What measures can be put in place to improve the teaching of Technology?

Research design
This study uses both quantitative and qualitative approaches. Quantitative approach deals with data that are principally numerical. Data is presented statistically and the results are presented with numbers (Cohen, Manion and Morrison, 2000: 89). This type of approach seeks facts as well as the cause of social phenomenon. It is objective, obtrusive and has a controlled measurement (Leedy and Ormord, 2000: 114). The use quantitative approach enables the researcher to gather views of large number of participants in a short time of study and produces concrete numeric results which can be easily analysed and reported. On the other hand, qualitative approach deals with data that is principally verbal and presents facts (Burns, 1999: 387). This type of approach is concerned with understanding behaviour from the actors' own frame of reference. It is subjective, naturalistic and has uncontrolled observation. In addition to that it is valid, that is, it has real, rich and deep data, it is holistic and is generalisable. Qualitative approach allow participants to give their views in a more open-ended way. Both qualitative and quantitative approaches assist in triangulation i.e. to back up one set of findings from one method of data collection underpinning by one methodology with another very different method underpinned by another methodology (Palgrave, 2006: 75, on line). Cohen et al. (2000: 92) stress the notion that if both approaches are used, factors raised in the quantitative data collection will be backed up by the data collected through qualitative data collection.

Participants
The targeted population consisted of all Further Education and Training Band teachers offering Technology in 12 high schools in the Ngaka Modiri Molema District within the North West Province. The number consisted of 60 teachers teaching Technology, 12 heads of Department for Technology and six (6) Subject Advisors for Technology based at the district office. The total population was 78.

Sample and sampling procedure
Purposive sampling was used to select schools. Creswell (2007: 125) indicates that through purposeful sampling the inquirer selects individuals and sites for study because they can purposefully inform an understanding of the research problem and central phenomenon in the study. According to Cohen et al. (2000: 73) in purposive sampling, the researcher handpicks cases to be included in the sample on the basis of his / her judgement of typicality. In the Ngaka Modiri Molema District twelve (12) schools which were the only ones offering
Technology in the FET Band were selected. The selected schools represented rural schools, urban schools and former model C schools. Four (4) teachers offering Technology in grade 10, 11 and 12 in each school; eight (12) Heads of Department for Technology from each school and six (6) Subject Advisors for Technology from the province formed part of the participants. The total sample was 66.

**Data collection procedures**

Permission from the Chief Operations Officer of the Department of Education in the North West Province was requested. Permission from principals of the 12 sampled high schools was also requested with an approval attached from the Deputy Director General. Arrangements were made in advance which included dates of delivering and collecting questionnaires. Appointments were made with heads of department to facilitate and collect the questionnaires from the colleagues. Questionnaires were hand delivered to sampled schools based on the number of teachers teaching Technology in each school. Structured interview was used because it provided a desirable combination of objectivity, depth and often permitted the gathering of valuable data (Sarantakos, 1998: 80). Appointments were also secured with selected Technology Heads of Department and Subject Advisors.

**Data analysis**

Quantitative approach was only applied to data that was collected through closed-ended questions. It was organized and presented with frequency and percentages then summarized by bar charts. Qualitative approach was applied to data that was collected through open-ended questions and interviews. Data was presented in narrative methods. The purpose for these data analyses was to form a basis for findings and recommendations (Cohen et al. 2000: 64) Data analysed is divided into three sections. The first section presents the teachers’ response to the questionnaire, followed by the heads of department interview responses and lastly by the subject advisors’ interview responses. The copies of teachers’ questionnaire, interview schedule for heads of departments’ and subject advisors appear as appendices D, E and F.

Example of a frequency and percentage table indicating educator responses on their readiness and support in the implementation of Technology

**Table 14: Readiness and support**

<table>
<thead>
<tr>
<th>Items</th>
<th><em>Columns</em></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Q14</td>
<td>19</td>
</tr>
<tr>
<td>Q15</td>
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<td>Q16</td>
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<td>Q17</td>
<td>12</td>
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<td>Q18</td>
<td>7</td>
</tr>
<tr>
<td>Q19</td>
<td>32</td>
</tr>
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</table>
tools and equipment in my school

<table>
<thead>
<tr>
<th>Q20</th>
<th>Technology is easy to teach and learn</th>
<th>35</th>
<th>58.3</th>
<th>25</th>
<th>41.7</th>
<th>60</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q21</td>
<td>I receive continuous training in technology</td>
<td>13</td>
<td>21.7</td>
<td>47</td>
<td>78.3</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Q22</td>
<td>Resources are available for teaching and learning Technology</td>
<td>22</td>
<td>36.7</td>
<td>38</td>
<td>63.3</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Q23</td>
<td>Assessment is easy to implement in Technology</td>
<td>31</td>
<td>51.7</td>
<td>29</td>
<td>48.3</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Q24</td>
<td>It is easy to record the performance of learners in Technology</td>
<td>43</td>
<td>71.7</td>
<td>17</td>
<td>28.3</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Q25</td>
<td>I need extra training in assessment for Technology</td>
<td>52</td>
<td>86.7</td>
<td>8</td>
<td>13.3</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Q26</td>
<td>The recording of assessment is time consuming</td>
<td>43</td>
<td>71.7</td>
<td>17</td>
<td>28.3</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>Q27</td>
<td>Assessment enhances the learning of Technology</td>
<td>56</td>
<td>93.3</td>
<td>4</td>
<td>6.7</td>
<td>60</td>
<td>100</td>
</tr>
</tbody>
</table>

Example of a bar chart indicating educator responses on their readiness and support in the implementation of Technology

Example of data which was collected through open-ended questions and interviews on challenges experienced by heads of department at the time Technology education was started in their schools.
Heads of Department interviewed indicated the challenges they experienced at the time they started implementing Technology. The responses below indicate some direct quotations from the heads of department interviewed:

**Interviewee A:** Learners from the GET-Band did not have good Technology foundation as well as lack of Technology equipments in our school.

**Interviewee B:** Some topics were very difficult.

**Interviewee C:** Learners from the middle schools did not have proper Technology foundation.

**Interviewee D:** My challenges were lack of textbooks, lack of Technology laboratory and unfamiliar topics.

The above responses show that by the time Technology was introduced as a new subject, heads of department were faced with some challenges summarized as follows:

- Lack of relevant textbooks
- New topics that were complex
- Learners from the GET-Band not having a good Technology foundation
- Lack of Technology tools and equipment

When subject advisors were interviewed about the availability of a plan for successful implementation of Technology, they responded in the following manner:

**Interviewee A:** We use the provincial instrument for continuous assessment.

**Interviewee B:** Yes, there is a vast need to train teachers. In the electrical Technology we have an electronic section on systems for grade 11 which teachers need thorough training on it.

**Interviewee C:** Yes, but there are some obstacles because there are no subsidy cars of which we have to rely on the pool cars to visit schools hence there are always some logistical problems. Furthermore, there is a need to support the GET – Band and FET – Band teachers. So, enough training is needed to train teachers.

Responses from the subject advisors indicated that even if a plan for successful implementation of Technology was in place to ensure its effectiveness, subject advisors were still faced with challenges to implement such a plan.

**Recommendations**
The following recommendations are made with the hope that they will assist the Technology Teachers and Department of Education in implementing Technology effectively

The Department of Education needs to upgrade the knowledge, skills and competences of Technology Teachers through continuous in-service training. This in-service training has to focus on the subject content knowledge and technological processes, that is, Investigating, Designing, Making, Evaluating and Communicating (IDMEC). There are Technology Teachers teaching Technology and who did not receive any formal training in the teaching and assessment of Technology but who are dedicated and determined to teach.

Attracting and retaining sufficient numbers of Technology teachers in the teaching profession is a serious problem. Emphasis must be that Technology teachers must be better paid to compete with the private sectors and other occupations. In addition, incentives in the form of bursaries should be used to recruit and select learners that have obtained good marks in
Mathematics, Science and Technology to train as Technology teachers at higher education institutions and enter into a contractual agreement with the government on completion of the studies. Furthermore, emphasis should be made to ensure that there are sufficient and attractive opportunities in the form of better salaries, bursaries to further one’s studies, accredited certificates of in-service training and trophies for achievements of teachers to get to know and appreciate innovative learning and teaching of Technology as a new subject.

The Department of Education needs to provide programmes that can equip teachers with competences to teach Technology at all grades that is, grade 10, 11 and 12 in the Further Education and Training Band.

Furthermore the Department of Education also has to provide a plan that will involve teachers to produce commitment to sustain the implementation of Technology and ensure its success.

Technology teachers in the General Education and Training Band must be competent enough to teach Technology to ensure that learners in the General Education and Training Band have a good Technology foundation, thus the teaching of Technology across the General Education and Training Band has to receive priority.

More subject advisors must be employed to ensure that they motivate teachers by monthly visits to schools in order to mentor and support teachers in the teaching and learning of Technology. There should be a plan for staff development and follow-up assistance to build and strengthen the support capacity at school and district level. Also to share expertise and knowledge through team teaching.

The Department of Education must provide high quality and relevant learning and teaching materials such as textbooks. “Teachers as Learners” (2007: 7) suggest that teachers should have access to high quality curriculum materials developed by people with expertise. In addition, there should be strategies to find resources to equip Technology laboratories in schools with tools and equipment to promote effective learning and teaching of Technology as a new subject. Fullan (1992: 83) suggest that resources are critical during the implementation process thus it is at the initiation stage that this issue must first be considered and provided for.

Conclusion
For Technology to be successfully implemented competent and qualified teachers are needed to teach in both subject content knowledge and teaching skills. Both the subject content knowledge and teaching skills should reflect a strong discipline component balanced with a good understanding of what is being taught with how to teach it. Technology teachers should share expertise and knowledge through team teaching.

The Department of Education needs to provide schools with relevant and adequate teaching learning materials that will improve the teaching and learning of Technology. Visible local, regional, provincial and national activities like Technology week, Technology shows, quiz, debates and speech contests should be there to promote Technology in our society. Technology teachers need to be encouraged to take part in these activities. Furthermore, Technology teachers should be encouraged to join Technology Teachers Association where they will able to share expertise and knowledge.
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Exploring the nature of knowledge building amongst teachers using the argumentation instructional strategy: Reflections from a community of practice

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Abstract

This article reports on a study conducted to explore the nature of knowledge building in a group of science education practitioners who have been introduced to an argumentation instructional strategy. Data on the reflections obtained from these practitioners were collected through a survey and were analysed using both quantitative and qualitative methods. The findings from the study have shown that argumentation is a critical tool, which, if applied to science education, will enhance rationality in the scientific discourse among science learners, thereby enabling them to conceptualise abstract concepts. From the findings, it has become apparent that science has a social construct, meaning that science can no longer be seen as separate from the socio-cultural setting of a community. Although the findings of the study show that argumentation presents significant opportunities for the social construction of knowledge in science education, a number of science teachers are not using it, citing a lack of pedagogical knowledge. The implications of these findings are discussed in detail in the study.

Key words: Nature of knowledge, argumentation instructional model, reflection, community of practice

Introduction

The paper is based on the reflections on the nature of knowledge building obtained from twenty participants who attended training workshops and seminars about the integration of science and Indigenous Knowledge (IK) using argumentation. The participants include, among others: teachers, teacher education facilitators, science education students, researchers in science education and individuals whose interests are in science education. These participants are part of the Science and Indigenous Knowledge Systems Project (SIKSP) group for a period ranging from six months to four years. Essentially, the SIKSP group is a Community of Practice (COP). The aims of the SIKSP project were to introduce participants to argumentation as an instructional strategy, to conduct research on the merits of using argumentation in science education, and to investigate how to promote the integration of IK and science in science education. Throughout this paper, we use the term science to mean “modern science” which in our opinion fails to take into account the socio-cultural backgrounds of the learners. In sum, the study reports on the nature of knowledge building among the participants who were exposed to the Argumentation Instructional Strategy (AIS). In their responses, they described their growth paths after being exposed to AIS.

We begin by explaining what argumentation entails, before discussing the rationale for using argumentation in science classrooms. Recent lines of research (Driver et al, 1999; Krummheur, 1995) have shown that at the core of effective classroom science discourse is
the use of argumentation. An argument is either individual or monologue – i.e. a single line of thought, or it is dialogical and social – particularly where a number of contrasting reasoning lines are developed (Billig, 1987; Driver et al, 2002). According to Billig (1987), an argument is discourse that presents an individual’s view point. Kuhn (1993) further explains that both individual and social arguments lead to higher order thinking or internal argumentation. Kuhn adds that, through participation in social dialogue, internal thinking strategies that are embedded in argumentation can be exposed or externalised. In this paper, we hold the view that the difference between “a discussion” and “an argument” is that an argument is a sub-set of a discussion, whose aim it is to resolve a specific controversy. However, we have used the terms “discussion” and “argument” loosely to mean the same thing.

Based on the above explanations, argumentation can be defined as the construction of knowledge through discourse. It can also mean persuasion. Eemeren et al (2004) and Meyers (1990) define scientific argumentation as constructing knowledge by using data or evidence, either empirical or theoretical, to support a claim. However, there are few opportunities for the social construction of knowledge in science education, hence the urgent call for the promotion and adoption of AIS in science education (Duschl & Osbourne, 2002; Driver et al, 1998, 2000; Erduran, 2006; Kuhn, 1992’ Ogunniyi, 2009). The next section looks more closely at argumentation theory. We have used the terms argumentation theory and argumentation synonymously throughout this paper.

What is argumentation theory?

The South African Government is in the process of implementing a new curriculum whose ethos includes acknowledging the rich cultural heritage of its multicultural societies and encouraging greater learner centeredness in teaching and learning science (DST, 2004; NCS, 2002). The inclusion of IK in the science curriculum calls for teaching methods, where learners become active participants and educators become facilitators. In such a context, argumentation is an effective forum for encouraging the active participation of learners. Toulmin, Rieke and Janik (1984:14) defined argumentation as “the whole activity of making claims, challenging them, backing them up by producing reasons, criticising those reasons, rebutting those criticisms, and so on”. In this paper, we refer Toulmin’s (1958) Argumentation Pattern (TAP), which has featured prominently in science education research in recent years. Essentially, the TAP consists of six components in reasoning, from obtaining and presenting data to claiming knowledge. These components consist of: data (facts or evidence that support a claim or an assertion), a claim (an assertion, a declarative statement or a conclusion whose merits are to be validated), warrants (these are the reasons that are proposed to justify the relationship or connection between the data and the claim), backings (basic assumptions, which are commonly agreed to provide justification for particular warrants), qualifiers (specific conditions under which the claim can be either accepted or limited), and rebuttals (these are valid counter-claims) (Bulgren & Ellis, 2012; Driver et al, 1998, 1999; Ogunniyi, 2007; Duschl, 2008). Before we delve into the implications of argumentation in science education, we need to acknowledge that, whilst the TAP provides a useful structural account of arguments, it needs to be supported by socio-cultural contexts for meaningful discussions to take place. We believe that there is a convergence between advances in educational theories that have been inspired by socio-cultural models of learning, and advances in the theory of argumentation (proposed by Toulmin’s [1958] argumentation theory). Therefore, in order to enhance the role of argumentation in science education, we propose that teachers adopt a teaching approach that promotes the use of argumentation.
within the framework of situated learning (Driver et al, 2000; Munford & Zembal-Saul, 2002).

**Implications of argumentation in science education**

There have been growing concerns about the hegemonic power of western science and its lack of social context in how it tends to portray nature (Aikenhead, 2002; Battiste, 2005; Ogawa, 1995). Worldwide there has been an increase for science education to be more pluralistic in approach, by calling for the inclusion of other ways of interpreting nature as part of the science curriculum. South Africa is one of the countries in the developing world whose curricula are being restructured to be more inclusive of its peoples’ different cultures as a way of making learning more meaningful and relevant to learners (Onwu & Mogege, 2004; Ogguniyi, 2007). Meaningful science learning in this regard is captured by Aikenhead’s (1997) assertion that classroom science would be more relevant to indigenous learners if it were guided by a curriculum framework that acknowledges IK. The integration of IK with science in learning and teaching calls for a change in teaching strategies, and specifically for the adoption of argumentation in science teaching (Ogunniyi & Kwofie, 2011; Siegel, 1995; Oggunniyi & Ogawa, 2008). This has led to studies that focus on the analysis of argumentation discourse in science learning and teaching contexts. The use of argumentation has important implications on teaching and learning in science education. The reasons are many and varied. Firstly, the use of argumentation in the classrooms provides learners with the opportunity to experience scientific practices foregrounded in and applied to contexts that are familiar to the students. In other words, students would learn about science broadly – including its intrinsic values instead of merely knowing the science concepts (Brown et al, 1989; Driver et al, 2000). Secondly, through argumentation, learners become active participants in the construction and production of scientific knowledge as opposed to mere consumers of knowledge (Boulter & Gilbert, 1995; Driver et al, 2000; Erduran et al, 2004; Jimenez-Aleixandre et al, 2000; Knorr-Cetina, 1999) Thirdly, argumentation recognises the existence of science and IK as different ways of thinking, which facilitates science learning by acknowledging the role of language, culture and social interaction in the process of knowledge construction (Vygotsky, 1978; Wertsch, 1991). Fourthly, using argumentation in the classroom makes the learners’ understanding and thinking processes visible to the teachers, which thus represents a tool for both assessment and self-assessment for learners and teachers respectively. Finally, argumentation allows the learners to participate in public discourses outside the science classrooms; this means that the skills they learn by presenting a cogent, logical, rational argument in the classroom can be applied outside the school environment – thus contributing to the development of good citizenship (Jimenez-Aleixandre & Erduran, 2005). The skills gained by learning argumentation in a science classroom are critical for the development of citizenship. Young people will need to confront complex public issues such as air pollution, genetic engineering of foods, healthy life styles and the use of organic fertilisers. Not only are these issues complex, but they also require complex data analysis. In this paper, we argue that for the learners to understand these public discourses and to make an informed judgement on a particular public issue, they will need to understand the claims and counter-claims that are being made and to consider the evidence provided in the discourse. This involves putting argumentation into practice. According to Driver et al (1998:301), argumentation is also important in public discourse in the sense that it provides the public “with a more authentic image of what is involved in scientific inquiry”. In conclusion, we thus posit that argumentation lies at the heart of knowledge construction in science and in society in general.
COP – SIKSP group

We have alluded to the fact that this study is based on the reflections of teachers in a COP. “Communities of practice are a group of people who share a concern or passion for something they do and learn how to do it better as they interact regularly” (Wenger, 2004:1). The SIKSP group is one such group; it is made up of science teachers, teacher education facilitators, science education students, researchers in science education and individuals whose interests lie in science education. Their common interest centres on the integration of science and IK. In addition, the SIKSP group’s aims are to: produce teaching resource materials for science teachers, create awareness of how IK and science can be integrated, to build IK data that could be used by science teachers as resources, and use postgraduate research as a vehicle to deepen their understanding of argumentation. In view of the differences between Science and IK, they also use argumentation as a way of evaluating scientific claims, challenging, backing and rebutting them (Rieke and Janik, 1984; Toulmin, 1958).

Three components make up the COP. First is the domain, which refers to the shared goals of deepening understanding of the integration of IK and science through argumentation. Second, community members engage in joint workshops, seminars, lectures and research, including reflections about the integration of science and IK. The last component is the practice: As practitioners, group members and teachers develop a shared repertoire of resources, such as: lesson plans, notes, science kits, theories of learning, research outputs. They furthermore reflect on their practices.

Reflective practices

The SIKSP group as a COP values reflective practices. Loughran (2002:33) defines a reflective practice as: “…a meaningful way of approaching learning about teaching so that a better understanding of teaching, and teaching about teaching, might develop”. Reflective practices are important in two ways: firstly, they offer a variety of approaches to examining practice and researching some of the assumptions that influence our daily work as teachers. Secondly, they provide an opportunity to understand the professional experiences of teachers (Brookfield, 1995). Although there are many types of reflections, for the purposes of this study, we will only focus on three. The first is the personal reflection, which is concerned with one’s personal growth, including one’s thoughts, actions and relationships with students. It connects the teacher’s identity to the teaching profession, seeking to understand whether the individual’s career goal suits her/his personality. Such personal reflections lead to introspection (Colbourne and Sque, 2004), which enhances self-awareness; practitioners also look at how their personalities affect their learners. Personal reflection goes beyond pedagogy to include issues such as the learners’ cultural, ethnic or life struggles, including their goals. The second type of reflections is contextual reflections, which look at concepts, theories and methods in science education. It includes interactions with other things, for example, teaching concerns about students and colleagues, curriculum, instructional strategies, rules, classroom management, and the communities from which learners come. With all these pressures facing the teacher, he/she must choose the most suitable and effective path to follow in the classroom. The third type of reflections concerns one’s personal teaching performance. So-called reflection-in-action takes place whilst the lesson is in progress, whilst reflection-on-action happens after a lesson, and it is the most commonly practised form of reflection by teachers (Carlo, Hinkhouse & Isbell, 2010; Larivee, 2000; Valli, 1997).
Focus of the study

The study is based on the reflections of twenty participants belonging to the SIKSP on the issue of using argumentation in the science classroom, and the integration of IK with science education. The participants are mostly postgraduate researchers in science education or individuals whose interests lie in science education. From their reflections, three domains of knowledge building were identified, namely, self-awareness, intellectual growth, and the nature of IK and the nature of science. These three domains will be discussed under the findings section.

Research question

The research question underpinning this study is: What is the nature of knowledge building among teachers in the SIKSP group, using argumentation as an instructional strategy?

Method

This research was carried out using both a qualitative and a quantitative approach. Twenty participants from the SIKSP group responded to a survey, which comprised the following four open-ended questions:

1. How have your experiences in the SIKSP or related activities (modules, seminars and workshops) informed the way you frame (i.e. bring coherence to, or make sense of) the pieces of information or experiences you have acquired, particularly in terms of the way you construed the controversial issue of integrating science and IK at the time you started participating in the activities, during the period of your involvement, and now?
2. Were you once opposed to the new curriculum? If yes, why? If not, why not? Have you changed your view over time and, if so, how?
3. How have you leveraged, reorganized or integrated your frames with your personal experiences with respect to science, IK or the integration of IK and science in the classroom?
4. How have the frames constructed from your experiences in the lectures, seminars and workshops prepared you to use argumentation instruction in teaching a controversial subject, such as the integration of science and IK?

Responses from these questions were intended to provide an overview of the nature of knowledge building among teachers in the SIKSP group who are either using argumentation as an instructional strategy in science classrooms or carrying out research work in science education. For the purposes of analysing the data, discourse analysis was used. Data from the responses of the teachers were coded and grouped into categories. From the categories, three domains emerged: self-awareness, intellectual growth, and awareness of the nature of IK and the nature of science emerged. Participation in the study by teachers was voluntary. For the purposes of qualitative analysis and anonymity, each teacher was given a pseudo-name identified by two capital letters, for example “AB”.
Findings

As mentioned above, three domains emerged from the analysis of the teachers’ reflections on the nature of knowledge building, namely: self-awareness, intellectual growth, and awareness of the nature of science and the nature of IK. Self-awareness, the first domain, can be construed as an understanding of one’s own knowledge, attitudes, beliefs and opinions in respect to argumentation as an instructional model and the integration of IK in the science curriculum. Self-awareness allows an individual to change thought processes and interpretations. Exposure to a practice such as the AIS develops self-awareness towards the practice, thus giving individuals clearer perceptions about themselves, such as their personality, including weaknesses, strengths, thoughts and emotions about the practice. It furthermore leads to self-efficacy (Bandura & Cervone, 1983).

The second domain, viz. relating to awareness of the nature of science and the nature of IK, covers the generally accepted notion by scientists of differences between science and IK. Science is regarded as universal, whereas IK is restricted only to a particular geographical location and to a unique socio-cultural environment: they thus represent two different world views. Science focuses on knowledge while to a certain extend giving less attention to the notion of science knowledge as a social construct, whereas IK views the world in a holistic way. In this paper, we posit that science and IK can co-exist in a multi-cultural approach in teaching classroom science (Aikenhead and Jegede, 1999). It is worth noting that in this contemporary world, knowledge is constantly changing to accommodate new ideas (Agrawal, 1995, Morphy, 1991, Snivel & Corsiglia, 2001).

Lastly, the third domain of intellectual growth is not merely about knowing facts and knowledge accumulation about a phenomenon, it is also about making connections with world views and locating one’s self within the context of other people’s beliefs. In addition, according to the teachers’ reflections, intellectual growth is enhanced by doing postgraduate research, participating in the production of science and IK learning materials, and using argumentation to integrate science and IK in schools.

In the following section, we discuss the reflections from teachers within the three domains.

The first domain: Self-awareness

In this self-awareness domain, the analysis of the teachers’ reflections on the integration of IK and science in the new curriculum has raised three issues. Firstly, eleven (55%) of the participating teachers said that they were in favour of the section of the new science curriculum that sought to integrate IK into science, giving five reasons. Five (25%) of the participants argued that such integration would add a socio-cultural perspective to science education; in other words, it would increase awareness of culture and identity. In addition, it can also be argued that modern challenges, for example, environmental issues, are better solved from social and cultural points of view in addition to scientific approaches. In support of this view, one teacher (OA) claims:

“I was never opposed to the new curriculum because I understood its intent and purpose as being an attempt to bridge the distance between science and the lived experience of ordinary people in their communities and their cultural ways of learning.”
Table 1: Perceptions of teachers about integrating science and IK

<table>
<thead>
<tr>
<th>Category</th>
<th>Reasons</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>In favour of integrating IK &amp; Science in new curriculum (10)</td>
<td>To add a socio-cultural context to the learning of science (7)</td>
<td>7</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>IK informs modern science (3)</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>Opposed to integrating IK &amp; Science in the new curriculum (7)</td>
<td>Lack of support for teachers in terms of professional development and availability of resources (6)</td>
<td>6</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Lack of conceptual understanding of IK (1)</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Undecided (2)</td>
<td>Lack of support for teachers in terms of professional development and availability of resources (1)</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Failed to see the immediate benefits of the integration, such as: improving pass rates in science, change in the South African science community (1)</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

Seven (35%) of the participants were of the view that “IK informs modern science”. Key to this assertion is the realisation that, even though IK and science are based on different world views, they complement each other. Additionally, Table 1 above shows also that the other reasons, though they did not feature prominently, were a lack of conceptual understanding of IK, and a lack of professional development programmes and teaching resources. One teacher (AM) stated:

“I was opposed to the new curriculum because it carried new content, which required more training, research and new thinking. I wasn’t so much equipped to face it.”

Secondly, among the teachers who took part in the survey, seven (35%) indicated that they were opposed to the integration of science and IK in science education, giving two main reasons. Six of the seven teachers in this category said they were opposed to the integration because of a lack of support for teachers in terms of professional development and because of a lack of teaching resources. One teacher (DM) declared:

“I also realized the teachers were not ready for this type of curriculum, especially the section where the integration of science and IKS is required. I still feel teachers need to be professionally developed on how to integrate science and IK.”

DM is referring to the lack of professional development that is exacerbated by a lack of relevant qualifications among teachers; according to research, these are some of the current challenges faced by South African teachers (Makgato & Mji, 2006; Reddy et al, 2006).

Lastly, two participants acknowledged that they were undecided about the integration of IK and science, one of them saying that he/she did not see how this integration would improve the pass rates in sciences in high schools or how it would help to enhance the scientific literacy of the communities. This argument was echoed by one of the teachers (SS) who stated: “My other confusion was how this may help to solve the current high failure rate in
science that South Africa is experiencing.” The participant (SS’s comments brings to our attention one of the broader challenges faced by the South African science education – the issue of high failure rates in science. There could be several reasons which results in the poor performance in science subjects. In the light of the discourse of this paper, we argue that bringing in IK in science education could be a way of anchoring the teaching of science in the socio-cultural contexts of the learners. This would give relevance and meaning to science education, in addition to motivating the students.

The second domain: Awareness of the nature of science and the nature of IK

In Table 1 above, the reason cited by five (25%) of the teachers in favour of the integration of science and IK was “to add a socio-cultural context to the learning of science”. This is testimony to show that IK is a social construct, whereas modern science is made up of components that are universally accepted. Examples of such components are concepts such as weight and length. In contrast, IK communities had different ways of measuring weight and length. Not all IK is compatible with science, however. Some researchers have shown that concepts such as the atomic model, which are not necessarily dependant on the socio-cultural context of knowledge, may not be assimilated through the integration of IK and science (El-Khalick & El-Mona, 2010). This is succinctly articulated by one of the participants (SD), who noted: “I feel it is important to isolate IK practices which have a practical or empirical application and then compare that to the modern science application.” We find (SD)’s argument relevant in the sense that in supports the notion that IK to some extend informs modern sciences – in a more validated manner.

The third domain: Intellectual growth

Teachers working on the integration of the two world views relating to IK and science have been involved in various intellectual activities, such as: postgraduate research on IK and science, development of IK and science teaching resources, and at personal level, identifying how the intrinsic values of IK and science can jointly benefit communities. Seventeen (85%) of the participants surveyed are in fact doing postgraduate research on IK and science – focussing on the use of argumentation as an instructional strategy in the teaching of high school science. Through research and postgraduate studies, teachers deepen their understanding of the nature of IK and the nature of science. One teacher (FG) claimed: “When exposed to IKS in my honours and Master degree training, the relevance and importance became clearer to me.”

A deeper understanding of the two world views has important implications in the teaching of school science – put more simply, teachers who are empowered or knowledgeable about IK are most likely to integrate it in their teaching. Intellectual growth was also facilitated by activities such as designing and producing an IK and science resource book, which was intended to alleviate the lack of such teaching materials. Six (30%) of the teachers said that they had acquired the intellectual capacity to apply the knowledge gained in SIKSP workshops, seminars, research and lectures to other socio-cultural contexts of their lives, such as the use of traditional herbs to treat minor ailments, for example, neutralising the pain experienced by an individual after being stung by a bee. They cited numerous examples where they used IK; one teacher (BM) explained, for instance:

“I have integrated this knowledge in various ways at grade nine level (natural sciences). For example, I have introduced indigenous sanitary pads for girls during...
The menstrual cycle (Reproduction). I have also engaged them in various debates concerning use of various indigenous medications for various ailments."

The classification of knowledge between the three domains of self-awareness, awareness of the nature of IK and the nature of science, and intellectual growth is quite weak (Sadovnick, 1991). This means that these three domains are not mutually exclusive, to the extent that some of the descriptors discussed, for example under intellectual growth, could well be pertinent to another domain and vice versa.

**Conclusion**

In our analysis of the reflections of teachers on the role of AIS in the integration of science and IK in science curriculum, we are cognisant of the fact that AIS is a new field that has only emerged in the last decade within the broader context of science education. Through analysing the reflections of teachers in the SIKSP group, several important points relating to the use of argumentation in science education surfaced. Firstly, there is significant support for the use of AIS in the teaching of science in school from the SIKSP group. On the one hand, this was expected, given that the SIKSP group is a COP whose prime goal is to deepen their understanding of AIS through research and science classroom practice. On the other hand, there is also growing acknowledgement of the key roles that AIS plays in science education. However, recent research (Kuhn, 1993 & 1992) has shown that, for various reasons, the adoption of AIS in science education at classroom level has made only very insignificant progress. One of the main reasons for this appears to be the lack of skills on the part of teachers on how to use AIS, coupled with a lack of teaching resources. If AIS is to be used in science classrooms, then greater emphasis needs to be placed on teacher training and professional development programmes that enhance their pedagogical knowledge of this teaching method. The SIKSP group as a COP is an excellent example where shared experiences on AIS have resulted in personal and intellectual growth. The findings have also shown that science has a social construct, meaning that science can no longer be seen separate from the socio-cultural setting of a community. This study has found that the missing link in ensuring successful learning in developing countries is the integration of IK and social and cultural contexts into science education, supported by the greater use of AIS. In fact, successful science learning environments, we argue, should be fostered when science features significantly in popular culture or IK (Dzama & Osborne, 1999). Hence, in conclusion, we posit that, if the future of teaching science lies in its ability to empower students with the skills to think scientifically about public issues that require informed citizens to make judgements, then AIS should be central to science education.

**References**


A case study using dialogical argumentation to explore grade 10 learners’ scientific and indigenous beliefs about lightning

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Abstract
This paper is based on a wider study on the relative impact of an argumentation-based instructional intervention program on grade 10 learners’ conception of lightning and thunder. In that main study, 16 grade 10 learners were exposed to a variety of activities that taught them the skills of effective argumentation. Using those skills, the learners were then involved in a number of other activities such as explaining observations that they made as they did experiments on static electricity. These activities were aimed at helping the learners to explore their understanding of science, indigenous knowledge systems and the nature of lightning. In some of those activities, the learners were presented with stories related to lightning and challenged to work out possible explanations of causes of lightning and to support their positions with evidence. The learners had to interact with these stories at individual, small group and whole group levels. This paper is based on those stories. Before the intervention program, the learners had been asked to state their knowledge or beliefs about the causes of lightning. The study showed that, initially, all the learners explained the causes of lightning in terms of science and none in terms of indigenous knowledge. After the activities on argumentation, science and indigenous knowledge and in response to the stories related to lightning, the learners seemed to realise and accept that science explanations of lightning were inadequate in explaining this complex natural phenomenon. Other explanations from indigenous knowledge systems are needed to supplement and compliment scientific explanations. The results show that a dialogical argumentation instruction can help learners to acquire a deeper, broader and more satisfying understanding of lightning. The implications of these research results are that teachers need to borrow from different worldviews when they teach about natural phenomena such as lightning and thunder to learners from indigenous groups of people.

Background
The Xhosa people, from whom the learners who were involved in this study came, hold very strong views on the causes, dangers and prevention of lightning. These learners demonstrated an impressive gamut of indigenous knowledge even before the intervention programme. In other words, such learners bring their own worldviews to the classroom. Unfortunately, this knowledge is normally largely ignored or marginalised, if not ridiculed, by the school as the curriculum tends to be biased towards Western forms of knowledge (Naidoo, 2005). In the science classroom the learners are taught another, different, explanation of these natural phenomena. The school explanation is given as the only legitimate way of explaining the phenomena (Ogunniyi, 2006, 2007a). The school science will, however, not replace the indigenous knowledge. The learners will continue to have their indigenous knowledge in their hearts and minds (Fanon,1967; Ogunniyi, 1988). The learner then now has two contrasting worldviews on the same natural phenomena, the indigenous and Western worldviews. Both are part of the student’s quest to make meaning of their lives and of their experiences. If this is not handled carefully, there could easily be cognitive dissonance in the minds of the learners when they cannot choose between the two worlds. New approaches that respect the epistemological and pedagogical experiences of the learners should be found and used if cognitive conflict within the learner is to be avoided or at ameliorated. One way of exploiting the positive virtues of both indigenous knowledge (IK)
and science is to integrate the two knowledge systems on an equal, mutually respectful, supportive and cooperative basis (Ng’etich, 1996).

Erduran and Jiménez-Aleixandre (2008) content that internationally, the phrasing of the national science curricula has begun to incorporate more of an emphasis on the need to teach students the skills of interpreting, evaluating and debating information. In short, the science curricula are putting an emphasis on the skill of argumentation because it is important in the construction of science knowledge and in life.

In South Africa, the introduction of Curriculum 2005 in 1997, saw a directive that compelled schools to integrate through argumentation science and indigenous knowledge in their science lessons. Learning outcome 3 of Physical Sciences, for instance, focuses on the Nature of Science and its relationship with technology, society and the environment when it states that the learner is able to identify and critically evaluate scientific knowledge claims; recognizing, discussing and comparing the scientific value of knowledge claims in indigenous knowledge systems and explain the acceptance of different claims (Department of Education, 2003, p. 14).

It seems clear that the new directive is that integration should be introduced in science lessons in South African schools. Later versions of Curriculum 2005 (C2005) such as the National Curriculum Statement (NCS) which was first examined in 2008 at Grade 12 level and the Curriculum and Assessment Policy Statement (CAPS) which came into effect starting with Grade 10 in 2012 have continued to call for the inclusion of indigenous knowledge in science lessons.

Integrating the two systems has its share of potential challenges (Aikenhead & Jegede, 1999; Department of Education, 2002). It requires careful planning and effective strategies. One such strategy is argumentation which is a tool that can be useful in resolving or harmonising two contrasting worldviews (IKS and Western science).

This research sought to find out ways of reducing or minimising the possible cognitive dissonance described above by using a dialogical argumentation instructional method aimed at helping learners to explore their scientific and indigenous beliefs about lightning. It was believed that dialogical argumentation could enable the learner to change or shift from his or her original point of view or worldview from scientific to IKS and vice versa when confronted with convincing and compelling evidence.

**The theoretical underpinnings**

In order to address the question of integration of indigenous knowledge with Western knowledge about lightning through argumentation, this study drew on theoretical frameworks associated with prior knowledge of learners such as the constructivist perspectives and the World View Theory.

The constructivist perspective supports the view that learning is a result of the interaction between the learner and the information the learner encounters and how the learner processes it based on perceived notions and existing personal knowledge (Yager, 1995 in Pabale, 2005). The construction of new knowledge is strongly influenced by prior knowledge, that is, concepts gained prior to the point of new learning (Ausubel et al (1978) in Naidoo, 2005). From a constructivist point of view, meaning is constructed as students interpret and reinterpret new events and new information through the lens of prior knowledge (Barnes, 1992; Berk & Winsler, 1995). Some constructivist approaches have emphasized the personal construction of knowledge while others have underlined the importance of social processes in mediating cognition. Science education would benefit from a synthesis of these two perspectives (Rivard & Straw, 2000, p.567-568). Prior knowledge includes the traditional knowledge that learners have and bring to the classroom. According to this perspective, school science learning can make more sense if it is related to the knowledge that the child
Brings to the classroom from his or her culture. This calls for integration of the two thought systems.

The World View Theory believes that every person has presuppositions about what the world is really like and on what constitutes valid and important knowledge about the world (Cobern, 1993 in Pabale, 2005). These presuppositions are the views that a person holds about natural phenomena. Worldviews which the students bring with them into the science classroom may affect not only how they make sense of science information, but also the extent to which they are willing to participate in the educational experiences. Care must be taken to ensure that indigenous learners do not feel like outsiders or guests in the school science classroom. The assumption is that, an education system that ignores or refuses to recognise the learners’ presuppositions, the learners’ worldview, is unlikely to be successful.

There are several theoretical frameworks that can be used to analyse arguments. These include Toulmin’s (1958) Argumentation Pattern (TAP) (Bell & Linn, 2000; Mason & Santo, 1994 in Tippet, 2009) and its various simplified versions and Ogunniyi’s (1988, 2000, 2004) Contiguity Argumentation Theory (CAT). Because of the problems associated with the use of Toulmin’s analytical framework (Simon, Erduran, & Osborne, 2006; Stone, 2009), this study, like other studies (Osborne, Erduran & Simon, 2004; Ogunniyi & Kwofie, 2011) adopted a modified version of the TAP by considering data, warrants, backings and qualifiers as evidence or grounds.

The Contiguity Argumentation Theory (CAT) (Ogunniyi, 2007a) deals with the nature of interactions between distinctly different thought systems such as science and IK. The theory is concerned with how distinctly different or conflicting ideas are resolved to gain a higher level of consciousness or understanding (Runes, 1975 in Ogunniyi, 2011). When two different cultures or systems of thought meet, co-existence can only be possible through cognitive shifts.

The importance of the categories of CAT in terms of this study is that Science and its explanations of the world has been the dominant thought system while indigenous knowledge and its explanations of the world has been the suppressed thought system.

The assimilated adaptive co-existence would mean the swallowing of indigenous knowledge by science or the use of science standards to judge the adequacy of indigenous knowledge. This study rejects that position.

The emergent adaptive co-existence would mean the addition of new information through school science to the already existing indigenous knowledge. This means building on, expanding and enriching the known (indigenous knowledge) by adding the unknown (school science). It could also mean the emergence of something new and different from either worldview, what Turnbull (1997) called ‘the third space’. This study accepts both meanings of the emergent adaptive co-existence.

The equipollent cognitive state would refer to a situation where a learner sees science and indigenous knowledge as two equally effective and legitimate ways of explaining natural phenomena or where the two thought systems complement each other. This study accepts that position.

This research makes use of aspects of each of these theoretical frameworks. This eclectic approach was chosen rather than using the full range of one model in order to tap the best from each of the models and to obtain a more workable analytical model (Tippet, 2009).

The purpose of the study

The aim of this study was to examine the effect of a dialogical argumentation instructional method, based on stories, on grade 10 learners’ scientific and indigenous beliefs about lightning.
The research question
To fulfill the above purpose of the study, this research sought to answer the following question: To what extent can a dialogical argumentation instruction help to influence grade 10 learners’ scientific and indigenous beliefs about lightning?

Methodology
This study adopted the qualitative research approach which falls under the descriptive interpretive paradigm. This paradigm views reality as multi-layered, interactive and a shared experience interpreted by individuals (McMillan & Schumacher, 1993). Qualitative research believes in the existence of multiple realities and truths based on one’s understanding of what constitutes reality. This study rests on the premise that there are many ways of knowing and that natural phenomena have many possible plausible explanations. In other words, there is neither one truth about nor one explanation of natural phenomena.

This study adopted a case study research design. A case study is an intensive study and analysis of an individual unit. According to Best & Kahn (1993), a case study examines a social unit as a whole where “the unit may be a person, a family, a social group, a social institution, or a community” (p.193). In this study, the social group, the unit, the case, was a group of grade 10 learners in a high school in the Eastern Cape Province of South Africa. The advantage of a case study is that it “probes deeply” (Best & Kahn, 1993, p. 193) in order to “analyse intensely the multifarious phenomena that constitute the unit with a view to establish generalisations about the wider population to which that unit belongs” (Cohen & Manion, 1994, p. 106-107). In this study, that wider population is all the learners from the indigenous groups of people who have to grapple with contrasting worldviews in their daily lives.

The quality of the research instruments was improved through comments on the instruments from specialists; pilot studying the instruments in two neighbouring schools and using appropriate calculations such as the Spearman rank order correlation coefficient. Poor items were identified and either revised/reworded or discarded altogether.

The initial views of the 16 learners about lightning were sought through a questionnaire which was administered to them before the intervention programme. The learners were asked to indicate what they thought were the causes, dangers and prevention measures of lightning. Then the learners were presented with case studies based on stories related to lightning and challenged to work out possible explanations of causes of lightning and to support their positions with evidence. To facilitate and scaffold learner argumentation open ended questions (prompts) to elicit justification of a claim were used.

Results
The learners’ reactions to the questionnaire on causes, prevention and dangers of lightning

The following are the initial views of the learners about lightning.

On causes of lightning, the learners thought ‘lightning was caused by static electricity which is natural, where thunder clouds consists of negative and positive particles which combine and cause lightning”; ‘lightning is produced in thunderstorms when liquid and ice below the freezing level collide”; ‘lightning occurs between the charges in the cloud and opposing charges on object at ground level’. All these are scientific explanations of lightning. No learner referred to indigenous explanations of lightning. When asked how they would protect themselves and their property from lightning, the learners stated what to do and what not to do as follows: ‘hide shiny objects such as mirrors and metals”; ‘put rubber tyres on top of your house”; ‘put a stick of a tree called umkuma’ and then ‘do not sit or stand near windows or doors or isolated buildings or tall trees or a fireplace or electrical appliances or water sources during a thunderstorm’. Unlike their response on causes of lightning, the learners
were now borrowing from both science and indigenous knowledge for their protection against lightning.
The learners came up with a number of dangers associated with lightning. Their list included: ‘damages or kills animals and people’; ‘damages and destroys houses and electrical appliances’; ‘can cause fires, burns, damage to the heart, brain and nervous system’.

Learners’ reactions to stories related to lightning

The first story appeared in the *Daily Sun* of February 2008. The second story is a narration of an incident that is said to have taken place in an African village after two men had quarrelled at a beer party. The other two stories were taken from a *Physics* textbook by Pople (1996).
The purpose of these stories was to challenge the learners to work out possible explanations of lightning and to support their positions with evidence.
The stories were discussed after activities on argumentation had been done with the learners. This was done because we wanted the learners to use the learned argumentation skills to negotiate the explanation of lightning as given by the two worldviews.

*Learners’ responses to the first story*
The story in brief: A soccer referee was struck but not killed by lightning while officiating a game. The weather conditions did not suggest that there would be lightning as it was ‘just drizzling’. The referee, who had wanted to stop the game but was opposed by the soccer officials, was the only person affected by the lightning. The mother of the referee insisted that a powerful witch had sent the lightning to kill her son. The learners were asked to read the case study and then answer questions about it. The following are some of the questions they were asked to respond to: *Who or what did the mother of the referee believe had caused her son to be struck by lightning? What evidence did the mother use to defend her claim? Why do you agree or disagree with the mother’s claim? Why do you agree or disagree with her evidence? If you do not agree with the mother’s claim, explain your own claim why the referee was the only person struck by lightning. If the referee had died, would your explanation be different from the one you gave?*
The following table shows the responses of the learners when they were discussing the mother’s claim and her evidence. The table demonstrates the argumentation of the learners as they discussed the story.

*Learners’ group or consensus responses to the story*

<table>
<thead>
<tr>
<th>Group</th>
<th>Do you agree with the referee’s mother that an enemy sent lightning to kill her son and with her evidence that her son was the only person affected by the lightning?</th>
<th>What other explanation can you offer for the lightning strike on the referee?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Disagree</td>
<td><strong>Initial response:</strong> ‘there must be another explanation’&lt;br&gt;<strong>Final response:</strong> ‘the referee must have had something that attracted the lightning’</td>
</tr>
<tr>
<td>2</td>
<td>Agree</td>
<td><strong>Initial response:</strong> ‘because he was the only person struck by lightning’ ‘powerful witches can send lightning to their enemies’ ‘witches use dead people for their evil deeds’&lt;br&gt;<strong>Final response:</strong> ‘normal lightning cannot strike one person in a crowd’</td>
</tr>
</tbody>
</table>
The initial response was before scaffolding and prompting. The final response was after scaffolding and prompting.

Group 1 disagreed with the mother insisting that ‘there must be another explanation’. Later on they said ‘the referee must have had something that attracted lightning to him’. Group 2 added as further evidence that ‘powerful witches can send lightning to their enemies’ and that ‘witches use dead people for their evil deeds’. After re-examining the meaning and differences between knowledge claims and evidence through class discussion and use of examples, the group was able to appreciate the fact that what they had added as evidence could be taken as knowledge claims that also needed to be supported with evidence. Leitao (2000) would, however, view these statements as counterarguments that are aimed at shifting the focus of the argumentation.

Groups 2, 3 and 4 agreed with the referee’s mother’s claim arguing that ‘because he was the only person struck by lightning’. Since this was just a repetition of the referee’s mother’s evidence, I challenged the groups to come up with their own evidence. Group 2 said ‘normal lightning would not strike one person in a crowd of people’. Again this was still the mother’s evidence put differently. After further discussions, Group 3 said ‘it was a message or a warning from the referee’s ancestors’. This was a different explanation to that given by the mother. Group 4 said that ‘perhaps he was in the path of lightning’. This was also an alternative explanation to that given by the mother. I wanted to know if Group 4 had changed their mind from their original position. They insisted that this was another possible explanation and that they subscribed to both explanations.

Through scaffolding using prompts, the learners threw arguments and counterarguments at each other during the open whole group discussions. For example ‘the metallic whistle the referee held attracted the lightning to him’ was met with ‘the whistle is too small to attract lightning from a cloud’ and ‘the sweat on the body of the referee attracted the lightning’ was met with ‘was he the only one sweating?’ and ‘he was the tallest person’ was met with ‘there is very little difference in the height of people, it is not like that between a tall tree and a person’.

Results and analysis of the learners’ responses to the other three stories

The second story in brief: A man’s homestead was struck by a bolt of lightning but the man was not at the homestead at that time. He had gone to another homestead for a beer party. A lightning bolt struck the homestead where there was the beer party but the man had left for his home (after seeing his homestead in flames). Before the man reached home, a third bolt of lightning hit and killed the man. It looked like the lightning was hunting for the man. This incident happened in an African village after the deceased and another man had quarrelled, a few days before this incident, at some beer party.

The third story in brief: A man had been struck by lightning three times, over a period of about ten years, dying of the effects of the third strike. A few years after his death, a lightning bolt hit the cemetery where the man had been buried. The bolt hit the man’s grave, the only grave to be hit. It looked like the lightning that had followed the man in his life had followed
him to his grave. This happened in Vancouver, Canada, during and after the Second World War.

The fourth story in brief: A man earned a place in the Guinness Book of Records for being the only known man to have survived seven lightning strikes. The man was a white American, in the United States of America.

For each of these three stories, the learners were asked their feelings about these stories and how they would explain why these people seemed to attract lightning.

The responses from the learners about these stories were quite different. The response of the learners to the African story was disbelief. ‘Did it really happen? Is it really true?’ the learners kept asking. On the contrary, the learners’ responses to the American stories was one of wonder, of awe. ‘Hey, how did that happen? How can that be explained?’ the learners asked. The difference is quite relevant and significant for this study. When I challenged them to offer possible explanations for these incidents, assuming these incidents were true, the learners differentiated the African incident from the American incident by maintaining that an enemy had sent the lightning to the African man. They could not explain how the American men were struck. Again this difference in response to the two sets of stories is significant for this study.

Discussion

The learners’ reactions to the questionnaire

The results from the questionnaire show that when the learners were asked the causes of lightning, none of them gave any cause related to the indigenous knowledge. All their explanations, although not always clear or accurate, were based on science. Elsewhere in this paper, I indicated that this group of learners had a very good repertoire of indigenous knowledge despite the many years of contact with the Western world and its ideas, including science knowledge. I am inclined to think that the fact that the learners did not include indigenous knowledge explanations of lightning was because they did not think that those indigenous knowledge explanations that they knew were important or valid. By extension, this means that these learners thought that the scientific explanations of lightning were better and superior to those of indigenous knowledge holders. For this group of learners, at this level of the intervention programme, the scientific explanations were the dominant view, according to CAT.

When the learners were asked how they could protect themselves and their property against lightning attacks, they came up with a mixture of prevention measures that came from both science and indigenous knowledge. This is to say that this time the learners were now informed by both worldviews for their answers. Why did they depend on only one worldview when they were discussing causes of lightning? The explanation for this apparent contradiction could be that when it came to preventive measures, the learners were using their practical experiences based on their observations of what happened in their communities where these methods of prevention are commonly used and are believed to work. They must have relied on their school science lessons to come up with the scientific methods of prevention. This example shows a situation where the learners are borrowing from each worldview in order to come up with a more comprehensive understanding of a natural phenomenon. The knowledge that they get is what Ogunniyi (2011) calls ‘the alloyed knowledge’. One could also describe this situation as equivalent to CAT’s equipollent category where two contrary ideas exist in the minds and hearts of the learners. Other people might not agree with this classification since, in this particular case, there were really no contrasting, but just different, points of view.

The learners’ responses to the first story
Group 1 rejected the mother’s indigenous explanation. To them, there must be some scientific explanation. They agreed with one learner who suggested that it was the metallic whistle that the referee held that attracted lightning to him. According to CAT, for this group, the scientific worldview is dominant over the indigenous knowledge worldview. Indigenous people might agree with Group 1 that the referee had something that attracted the lightning. The difference would be that the indigenous people might not think that that ‘something’ was the metallic whistle.

Group 3 agreed with the mother’s explanation and came up with a different explanation that was again informed by indigenous knowledge. (it was a message or a warning from the referee’s ancestors’). In terms of CAT, for this group, indigenous explanations were dominant over the scientific explanations. They found the indigenous explanation more appealing than the scientific explanation.

Group 4 initially agreed with the mother but later on said that ‘perhaps he was in the path of lightning’. This is an alternative explanation to that given by the mother. While the mother’s explanation is informed by indigenous knowledge, Group 4’s second explanation seems to be informed by science or by indigenous knowledge or by both. The statement that the man must have been in the path of the lightning is reasonable and logical. Both thought systems are reasonable and logical and so could have produced that kind of statement. Indigenous knowledge might, however, go further and want to know why he was in the path of the lightning in the first place and why him and why him alone. It is possible that Group 4 demonstrated Aikenhead & Jegede’s (1999) dependent collateral learning where a schema from one worldview (the scientific explanation, in this case) challenges a schema from the other worldview (indigenous knowledge explanation, in this case) to the extent of permitting the student to modify, with reason and conviction, the existing schema. In that case the group would have shifted from their indigenous knowledge position to embrace the scientific explanations. Group 4, however, seemed adamant that they subscribed to both explanations. They professed that they had not shifted their earlier explanation but had added another possible explanation. In terms of argumentation, this is in agreement with CAT’s assertion that learners can hold two opposed worldviews without experiencing cognitive conflict. CAT calls this the equipollent category, which refers to a situation where the learner finds the explanations of a natural phenomenon from two different worldviews equally powerful, convincing and appealing.

One can also look at the exchange of ideas between the arguers as they attempted to explain why a soccer referee was the only person struck by lightning from another angle. For this analysis and discussion, the speaker is the mother of the referee and the learners in their discussion groups are the arguers.

The speaker’s position or argument: an enemy sent lightning to my son.

Arguer 1: his ancestors have a message for him.
Arguer 2: the metallic whistle he held attracted the lightning to him.
Arguer 4: he was the tallest person in the crowd.
Arguer 6: he was sweating and it is the sweat that attracted the lightning to him.

All the statements from arguers 1, 2, 4 and 6 are counterarguments where a counterargument is defined as: ‘the view or the argument of a person who disagrees with or is opposed to the speaker’.

The following statements from the other arguers in response to the above arguers were rebuttals where a rebuttal is defined as: ‘a statement that attempts to disarm or weaken an opponent’s argument’; ‘a statement that tries to bring the merit of an explanation into question’.

Arguer 3: the metallic whistle is too small an object to attract lightning from the skies. (rebuttal to statement from arguer 2).
Arguer 5: *there is no much difference in the height of people.* (rebuttal to statement from arguer 4).

Arguer 7: *he was not the only person sweating.* (rebuttal to statement from arguer 6).

Further analysis of the explanations reveals that the explanations of the speaker and arguer 1 are probably informed by indigenous knowledge; the explanations from arguers 2 and 6 are probably informed by science; the explanation from arguer 4 is probably informed by both worldviews.

It is important, for this study, to note that the claims advanced by the learners during the open whole group discussions were all informed by science and that the counterarguments, while not offering alternative explanations, questioned the validity of those scientific explanations of the causes of lightning. It must be remembered that before the intervention programme, all the learners gave scientific explanations of the causes of lightning with none questioning them or giving the indigenous knowledge explanations. There seems to have been a transformation, a change of position amongst the learners. At the very least, they seemed to be saying: ‘the scientific explanations are not wholly adequate and satisfying’. The learners now appeared more accommodative of other possible explanations of lightning. Liphoto (2009), who studied the effect of a cross-cultural instructional approach on learners’ conceptions of lightning, came to a similar conclusion when he claimed that, as a result of that approach, “some learners accommodated both scientific and traditional conceptions of lightning ---- without experiencing any cognitive conflict” (p. 118).

In terms of argumentation, the groups were now able to respond to and challenge their opponents’ point of view; offer several possible explanations for a single event; and change their minds when confronted with convincing evidence. All these are skills associated with effective argumentation.

**The learners’ reaction to the other three stories**

The learners refused to accept the truth of the African story but they accepted the American stories. Their only problem with the American stories was that they could not explain them. When I challenged them to tell me the difference between these stories, they could not come up with any differences. To the learners, some Africans have the ability to create and send lightning to their enemies. Apparently, to the learners, white people do not have that ability. Also, the learners simply saw the ability to create and send lightning to others as an act of evil people against their enemies. They did not refer to this ability in the positive. This is understandable given the fact that there are no reported incidents where lightning, created by man, has been harnessed for the benefit of humankind.

**Summary**

From the above observations and interpretations, one thing seems to come out clearly and it is that these learners now embraced both worldviews as they sought explanations of lightning. Of importance to this study was the realisation and acceptance by the learners that the scientific explanation of lightning may not be adequate to explain the nature of lightning. Other explanations from indigenous knowledge systems may be needed. This development is extremely significant for this study that sought to convince learners that there are many viable knowledge systems that seek to explain the world around us. In other words, we need to borrow from different worldviews, if we are to fully understand natural phenomena such as lightning and thunder. These four stories illustrated this point very convincingly.

**Conclusion**

The results of the study seem to have shown and demonstrated benefits of learning environments that allow and support learners’ negotiation and navigation of different
worldviews and epistemologies through argumentation. The results are encouraging in that they seem to show that the learners’ skills in argumentation and their knowledge base of the scientific and indigenous knowledge explanations of the nature of lightning improved significantly as a result of this intervention programme. The use of stories, with their intrinsic motivational value and their natural settings, could have been the reason for the excitement that the learners demonstrated as they went through the research activities. Because of these encouraging results, this study recommends that the policy of integrating science and indigenous knowledge in science classrooms through argumentation, as enunciated by the Department of Education, should be supported by all the relevant stakeholders. The work of the Science and Indigenous Knowledge Systems Project (SIKSP) at the University of the Western Cape, where teachers are trained to integrate the two thought systems and where materials to do this are being produced must be supported by all and should spread to cover the entire country.

References


Teachers’ and teacher trainers’ reflexivity and perceptual shifts in an argumentation-driven indigenized science curriculum project

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Abstract

One of the aims of the new South African science curriculum has been for teachers to integrate in their classrooms two distinctly different knowledge corpuses namely, indigenous knowledge (IK) and school science. To achieve this aim an argumentation-driven indigenized science curriculum was developed. An argumentation framework was chosen because it has been reported in a plethora of studies to provide the needed atmosphere where teachers can freely express their views, clear their doubts and even change their views about implementing a presumably controversial curriculum. This paper reports the experiences of teachers and teacher trainers (henceforth subjects) involved in the development of an indigenized science curriculum. The data sources consisted of the subjects’ responses to a questionnaire, transcripts of interviews, personal notes and ‘reflective diaries’ or experiences over a period of two to three years. An analysis of the data showed a general perceptual shift among the subjects in favour of implementing the indigenized curriculum than was the case before participating in the project. Further, the subjects adduced justifiable reasons for their perceptual shifts, thus indicating the potential of argumentation for knowledge building and belief revision about professional practice.

Key words: Teacher and teacher trainers, argumentation-driven science curriculum, indigenous knowledge, reflexivity and perceptual shifts, reflective diaries.

Introduction

A plethora of studies have attempted to explicate the Kuhnian notion of revolutionary change in science (Kuhn, 1970) to teachers’ change in professional practice (e.g. Driver & Osborne, 1999; Erduran, Osborne & Simon, 2004; Simon, Erduran & Osborne, 2006; Skoumios & Hatzinikita, 2009). While these studies into teachers’ professional practice have merit their focus has largely been on the deployment of technical knowledge or skills for the purpose of developing specific tangible products or what Aristotle calls techne or poiesis rather than phronesis or praxis i.e. practical knowledge or wisdom critical to the acquisition to one’s sense of being or becoming in relation to others. Praxis depicts communally shared understandings and values vital for harmonious living in a given socio-cultural group. A close word to this is ubuntu i.e. togetherness or relatedness which underlie many a community of practice. Unlike the former which is based on the acquisition of technical knowledge or craftsmanship the latter is concerned about “doing the right thing and doing it well in interactions with fellow humans” (Schwandt, 2007: 242).

Another lacuna in the extant literature on teacher professional practice is the paucity of studies which have attempted to explore in a systematic way how and why teachers change practice e.g. after a sustained participative experience in an endeavour. Often teachers are at the consumers’ end of the curriculum development process rather than being active participants in the development of that curriculum. In this teachers tend to see the curriculum as an imposition (Author, 2004, 2007a & b; Jansen & Christie, 1999). A classic case of this is the new outcomes-based science curriculum published by the Department of Education (DOE) which demands teachers to teach and assess an indigenized science curriculum (DOE, 2002, 2011)) even though even though they had little or no input in its development. This
paper is based on a study that has attempted to ameliorate the situation by involving teachers and teacher trainers in the curriculum development such that they not only acquire technical or practical knowledge in the sense of a craftsman or *poiesis* but emancipatory knowledge or practical wisdom *phronesis* or *praxis* whereby they own the curriculum and run with it. For teachers to attain *phronesis* critical to emancipatory knowledge implies that they see the development and implementation of a curriculum as an activity worthy of their intellectual, moral and professional commitment. This implies giving them voice to express their views and their roles in the curriculum development process. Otherwise, they would consider such a curriculum as has often been the case with many a politically motivated curriculum. Ebenezer (1996) citing Fenstermacher’s notion of practical arguments deployed by teachers contends that unlike scientific paradigmatic shifts (Kuhn, 1970), teachers’ change in professional practice requires more than gaining specific instructional skills but also the deployment of practical wisdom (Habermas, 1999) and beliefs about professional practice as well. Further, Fenstermacher concedes that the change in teacher professional practice is a holistic affair which involves a change in the truth value of the premises and assumptions underlying their beliefs and convictions. In other words, to bring about even a miniscule change in their beliefs about practice implies getting below the outward veneer into the subconscious level which shapes their sense of being, dispositions, and intellectual interests.

The value of a science education programme aimed at improving teachers’ professional practice lies in determining what is required to modify the truth value of the knowledge (epistemology) and interest (axiology) reflected in their practical arguments e.g. by affording them access to communicative freedoms beyond their own self-conversation (intra-locution) as would be the case in interactive or interlocutory group context (Author, 2007a & b). But at the same time the change introduced into the underlying assumptions of teachers’ practical arguments must be compatible with their beliefs about the nature of professional practice. In other words, the teachers must be willing participants in determining the change in their own practical arguments to accommodate the new practice and to ultimately own it. Further, this implies respecting their autonomy and sense of identity (ontology) or ownership in determining what or not to believe or implement in practice.

The history of science attests to the fact that no revolutionary idea is accepted by the scientific community easily without a serious and sometimes a long-drawn battle between the proponent(s) and the opponent(s) of the new idea. In fact, in many cases the arguers died before their ideas were accepted by the scientific community (Kuhn, 1970). By extension it is preposterous to assume that teachers would easily give up their tenaciously held beliefs about practice on account of a few weeks or even months of exhortation about the value of a teaching approach. Rather, what tends to occur when people are exposed to new ideas or practice is a sort of back-and forth ontological reflexivity i.e. the process of critical self-reflection on one’s biases, viewpoints, theoretical predispositions, preferences and so forth (Schwandt, 2007). It also entails some form of appropriation, accommodation, amalgamation, integrative reconciliation and adaptation or an admixture of these (Author, Author & 2007a & b).

The decision to accept or reject a new idea or practice usually involves reflection and practical reasoning (self-efficacy) and practical wisdom or *phronesis*. In virtually all the attempts that have over the last three centuries to attain change in teacher professional practices a sort of Heisenberg’s “uncertainty principle” has tended hold, thus indicating the complexity of the whole process. However, in the last two decades, teachers have been given voice to engage in the process of reflexivity and praxis. One forum that has been effectively used in this regard has been to engage teachers in the process of argumentation. It was in the light of this that the present study opted to explore the potential of argumentation for
exploring the nature of practical arguments that a cohort of 25 teachers and teacher-trainers use for supporting or rejecting the new controversial indigenized science curriculum.

**Modelling professional practice through argumentation**

Since the turn of the 21st century many science educators have explored the potential of argumentation for generating classroom discourse and for determining teachers’ views on various controversial social issues (e.g. Bottcher & Meisert, 2011; Rose & Barton, 2012; Simon, Erduran & Osborne, 2006; Skoumios & Hatzinikita, 2009). A model of argumentation that has had an increasing usage in science education has been the Toulmin’s Argumentation Pattern-TAP (Erduran et al, 2004). Essentially TAP consists of a claim (an assertion in need of validation), data (evidence in support of the claim), warrant (a general statement linking the claim with the data)' backing (the underlying assumption to the claim), qualifier (the contingent condition in which the claim holds) and the rebuttal (possible exception to the claim).

The way TAP has been applied in many a studies has been criticized for various reasons e.g. the inconsistent way in which the validity of an argument has been presented (Eemeren, et al, 1987); the vagueness of the theoretical, methodological and analytical frameworks used; the overlaps of TAP elements (Bottcher & Meisert, 2011; and TAP’s inattention to counterarguments or alternative claims which may cast doubts on the speaker’s position (Leitao, 2000). To reduce the issue overlap Erduran, Osborne and Simon (2004) combined some of TAP’s elements evidence, warrants, backing and qualifier into grounds and used the frequency of rebuttals to judge quality of an argument (Erduran et al., 2004). Also, TAP seems to apply only to the formal logic at the expense cultural ethos which tends to shape the way people reason in a discourse. It was to capture the various levels of discourses in the classroom that the Contiguity Argumentation Theory (Author, 2007a; Author & Associate 2008b) was proposed.

To compensate for the limitations of TAP the Contiguity Argumentation Theory (CAT) draws on the Aristotelian contiguity notion of interacting ideas; it explores both logical and non-logical affective and socially embedded issues critical to the attainment of cognitive harmony. CAT consists essentially of five dynamic cognitive states that an arguer might use to appraise and adapt to different contexts. The five categories are: dominant-the prevailing idea worldview considered to be the most appropriate for a given context; suppressed-the subordinate worldview to a dominant one; assimilated-the worldview which capitulates to, or is subsumed by the dominant one; emergent-a new idea that is incorporated into an existing idea; and equipollent-a state in which two or more distinct ideas or beliefs co-exist and exert a comparable cognitive force on a person’s worldview. Each of these cognitive dimensions is in a dynamic state of flux and can change from one form to another depending on the context in question. A detailed description of CAT has been published elsewhere. It is also apposite to point out that the dynamism of CAT becomes handy in whatever context an argumentation takes place; be it at the intra- (self-conversation) level, inter- (group-conversation) level or trans-(larger- or across-groups conversation) level (Author, 2004, 2007a & b; 2011). The decision reached at all these levels of argumentation of course cannot be divorced from the arousal context which triggers off, as well facilitates the process of cognitive harmonization and consequently the stance that one takes relative to the subject matter in vogue.

**Habermas’ notion of practical arguments**

The notion of “practical arguments” used in the paper also draws on Habermas’ (1999) notion of “practical reasons” in terms of human right. In this regard, practical arguments depict people’s e.g. teachers/teacher-trainers’ ability to deploy certain practical reasons to justify
their stances or dispositions towards a given goal or demand such as the call on teachers to indigenize school science. However, the way the teachers respond to this demand cannot ignore the teacher’s rights to think or act in a way that does not necessarily accord with the demand. Nor can one take the teachers fundamental human rights to think or act on the basis of personal rather than communal interests. However, an argument on any matter e.g. the indigenization of school science would be pointless unless the teachers themselves are willing to surrender some of their individual rights or interests for communal rights or interests for the sake of achieving the common good. This subjugation of personal interests for community interests is fundamental to the democratic principle equal rights which in turn are a pre-condition for anyone to get involved in a discourse in the first place. As stated earlier, if teachers are not to perceive the new curriculum as an imposition, they must be given the opportunity to express their views about it and to respond accordingly. This implies that they are allowed to express their views in terms of what accords with their ontology-essence or sense of being, epistemology-theory of knowledge and axiology-beliefs, values and intellectual interests. To deny them of this right is to deny them a fundamental human right i.e. freedom of expression. In the context of any discourse, in this case the implementation of an indigenized science curriculum, it is assumed that: (1) no one able to make contribution is excluded; (2) all participants have equal rights to contribute; (3) the participants mean what they say; and (4) that communications are freed from internal or external coercion (Habermas, 1999).

In order to persuade teachers to accept an indigenized science curriculum or to consider change in practice they must have the opportunity to externalize their thought and clear their doubts about the new demands associated with that change. However, as the critics of the curriculum have shown this has not been the case. Neither have the teachers been given the opportunity to express their views based on their beliefs and moral conviction about teaching (e.g. Author, 2004, 2007a & b; Ebenezer, 1996; Jansen & Christie, 1999; Rogan, 2004). Yet, any endeavour undertaken to bring about change in teachers’ professional practice cannot ignore their sense of moral responsibility towards such a practice. The issue here is not simply to increase teachers’ content or pedagogical content knowledge though desirable, but also to give them the opportunity to re-appraise the validity of their own assumptions and beliefs about teaching. In the final analysis before teachers can consider a change in practice they must have the opportunity to weigh the merits and demerits of the new approach in terms of their own personal preferences.

The teachers’ practical arguments, since the inception of the new South African curriculum in 1997, has been that they have not been given sufficient opportunities and voice to express their views at the different levels of discourses surrounding the formulation, development and implementation of the curriculum. In the light of Habermas’ (1999) pre-conditions listed earlier, it can be said that our teachers have been given a raw deal, so to speak. This is even more crucial when it is realized that the same teachers are ultimately responsible for the implementation of the new curriculum. It was to create the needed intellectual space for the teachers to voice their concerns about the new curriculum that the study used a Dialogical Argumentation Model (DAM) to hear the teachers’ side of the story. It was thought that DAM: (1) would provide the teachers the needed opportunity to express their views about an arguably controversial curriculum; (2) was more amenable to classroom discourses than traditional instruction familiar to most teachers; (3) could serve as a useful indicator for detecting teachers’ belief revision concerning the curriculum; and (4) could reveal teachers’ beliefs, experiences and the practical reasons they deploy to justify their dispositions towards the curriculum.

449
Purpose of the study
The central concern of the paper was to explore the practical arguments that teachers involved in the study used to justify their support or rejection of the new curriculum. The underlying philosophy of DAIM is that the subjects should be free to express their views and justify their stances not only from their scientific beliefs but also religious beliefs about professional practice.

Methods
Argumentation has been shown to be a veritable tool for discourses and for meaning sharing in the classroom (Kuhn, 1993). Before the actual study commenced the 25 subjects participated in a three-hour per week argumentation sessions for four weeks. The focus of these sessions was on topical or controversial issues e.g. the fairness/unfairness of differential electricity rates based on people’s socio-economic statuses; the construction of a five-star hotel in a wetland near a big city; the building of additional atomic power stations to cope with electricity demand; and the planned reduction in the use of coal for generating electricity to reduce environmental pollution. In the last session an enthusiastic participant prepared her grade 11 students to debate the controversial issue of whether or not to make school uniforms compulsory.

The initial lectures of SIKSP focused on the nature of science (NOS) and the role of argumentation in scientific practice. Some of the topics covered include: NOS as espoused by renowned scholars; pre-Socratic debates on the nature of matter; Ptolemaic geo-centric versus Copernican helio-centric systems; Semmelweis’ childbed fever case; controversies that surrounded the structure of the atom; Eccles’ electrical versus Dale’s chemical nerve transmission of impulses across synapses; etc. To prepare for each lecture, the subjects read several papers on NOS from the historical, philosophical and sociological viewpoints. Each lecture lasted for one and half hours followed by another hour for arguments and discussions. The last 30 minutes was used for recapitulation and summary. The workshops underpinned by the same argumentation framework involved hands-on inquiry activities coupled with assigned cognitive tasks in the work sheets tackled at the individual (intra-argumentation), small groups (inter-argumentation) and the whole group (trans-argumentation) levels of discourse; the goal being to reach consensus (cognitive harmonization) where feasible (Author, 2004, 2006, 2007a & b, 20011; Author & Associates, 2008a & b).

This section provides both quantitative (Table 1a & b) and qualitative summaries (in form of excerpts) derived from the subjects’ reflective experiences in the SIKSP lectures and workshops.

Table 1a. Emerging themes in Q1-3 from the subjects’ reflective diaries on an indigenized science curriculum

<table>
<thead>
<tr>
<th>Themes</th>
<th>frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unaware that science might have had an indigenous or local knowledge origin</td>
<td>36</td>
<td>19</td>
</tr>
<tr>
<td>Ignorance and lack of awareness about IK or its relevance to science</td>
<td>30</td>
<td>16</td>
</tr>
</tbody>
</table>
SIKSP using dialogical argumentation instruction (DAI) helped understand the nature of IKS

<table>
<thead>
<tr>
<th>Statement</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Africans have developed a nonchalant attitude toward indigenous values</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Sub-total</td>
<td>188</td>
<td>100</td>
</tr>
</tbody>
</table>

2a: In what ways have your experiences in the SIKSP or related activities (modules, seminars and workshops) informed the way you frame … or teach a controversial topic such as integrating science at the beginning, during and after experiencing SIKSP?

<table>
<thead>
<tr>
<th>Statement</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>I was ignorant or unaware of IK before joining SIKSP</td>
<td>26</td>
<td>30</td>
</tr>
<tr>
<td>I had a knowledge of IK before joining SIKSP</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Science alone shaped my worldview before I joined SIKSP</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>SIKSP based on DAI has helped me to value IK and know how to integrate it with science</td>
<td>20</td>
<td>23</td>
</tr>
<tr>
<td>I now support the integration of science and IK</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>Lack of training and an exam-driven curriculum are still and obstacle to integration</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Sub-total</td>
<td>88</td>
<td>100</td>
</tr>
</tbody>
</table>

Q. 2b: Were you once opposed to the new curriculum? If yes, why? If not, why not. Have you changed your view over time and if so how?

<table>
<thead>
<tr>
<th>Statement</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>IK was seen as valuable</td>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td>I was opposed to IKS before SIKSP but now I want to integrate it with science</td>
<td>16</td>
<td>37</td>
</tr>
<tr>
<td>Opposed new curriculum because teachers were not trained or equipped</td>
<td>13</td>
<td>30</td>
</tr>
<tr>
<td>Still opposed to new curriculum because of inadequate training and provision made</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>Sub-total</td>
<td>44</td>
<td>100</td>
</tr>
</tbody>
</table>

Q. 3: How have you, or in what ways have you leveraged, reorganized or integrated your frames with personal experiences with respect to science, IK or the integration of both in the classroom?

<table>
<thead>
<tr>
<th>Statement</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Now believes that some indigenous knowledges have science and use similar methods as in science.</td>
<td>22</td>
<td>32</td>
</tr>
<tr>
<td>Integrating science and indigenous knowledge through argumentation leads to richer experiences to both the teacher and learners.</td>
<td>19</td>
<td>28</td>
</tr>
<tr>
<td>Integrating science and indigenous knowledge will make classroom science teaching and learning more relevant to learners’ experiences</td>
<td>14</td>
<td>20</td>
</tr>
<tr>
<td>Have integrated science and indigenous knowledge in the classroom successfully</td>
<td>12</td>
<td>17</td>
</tr>
<tr>
<td>Supporting and looking forward to introducing the Science-IK integration in the classroom</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sub-total</td>
<td>69</td>
<td>100</td>
</tr>
</tbody>
</table>
Results and discussion
Reflective diary is construed in the paper as a retrospective appraisal of one’s experiences. The quantitative descriptions focus mainly on the subjects’ responses to an open-ended questionnaire consisting of five items (Table 1a and b). For the same reason only snippets of the qualitative data on Q2 are presented in the paper. To present the responses of all the 25 subjects to all the five items would require a much longer paper. Nevertheless, it is hoped that what is presented would show to some extent the effectiveness or otherwise of the argumentation model adopted in the study for promoting the subjects’ knowledge building and belief revision concerning an indigenized science curriculum to which they had been exposed and how this might have impacted their professional practice in general.

An examination of Q1 in Fig. 1a shows that of the many themes that emerged in the subjects’ reflective diaries. About one-fifth (19%) of the themes indicated unawareness by the subjects about the indigenous roots of modern science while 16% indicated unawareness about the relevance of science to school science. However, nearly three fifths of the themes (59%) showed that SIKSP based on a dialogical argumentation framework was helpful in facilitating the subjects’ understanding of the nature of IK. Similar themes emerged from Q2a regarding the impact of SIKSP on the way the subjects: frame their teaching (30%); value IK or its integration with science (23%), or now support the integration of science and IK (17%).

Q2b is concerned with the subjects’ stances on an indigenized curriculum before during and after being exposed to SIKSP. While 16% of the themes indicated valuing IK 37% were initially opposed but now support integration; 30% were in opposition for lack of any specific training while 18% had a change of heart due to lack of adequate training resources. Q3 is concerned with the effects of the subjects’ experiences in the SIKSP on their professional practice. 32% of the themes suggest similarities in the methods used in science and IK; 28% consider the dialogical argumentation model (DAM) used in the SIKSP enriched their experiences as well as those of their learners about the value of integrating science and IK; 20% indicated that an indigenized science curriculum made teaching and learner more relevant to their learners’ experiences while 17% indicated to having integrated science in their classrooms (Fig 1a).

Q4 deals with how frames constructed by the subjects’ experiences in the SIKSP have facilitated their efficacy in implementing a controversial topic like “indigenized science.” In this regard 23% indicated that the SIKSOP lectures and seminars have equipped them to understand the nature of science and IK and how to integrate the two worldviews in their classrooms. 39% thought that teachers are unable to integrate science and IK because they have not been specifically trained to do so. Further, the themes suggest 27% would not have considered the integration of science and IK feasible without having been exposed formally to SIKSP. This is corroborated by the fact that 16% attributed their ability to integrate the two worldviews as a result of participating in SIKSP. In the same vein when asked about the abilities needed by teachers to participate in argumentation 42% and 44% respectively indicated teachers’ knowledge and understanding of the nature of argumentation and teachers’ self-efficacy (i.e. ease and confidence) to teach an argumentation-based lesson. As to what factors facilitate or hinder the development of such abilities 38% and 26% respectively indicated the possession of argumentation skills through training and the ability to manage diversity, group work and the ability to scaffold argumentation practically. In terms of factors that could hinder the development of such abilities 22%, 39% and 29% respectively relate to time constraints due to the examination-driven curriculum, inadequate content or argumentation skills and factors such as large classes, dominance of the scientific worldview, cultural or second language related problems (Table 1b).
IK in your classroom?

<table>
<thead>
<tr>
<th>Statement</th>
<th>16</th>
<th>23</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIKSP workshops, seminars and lectures helped me understand NOS and IKS and to integrate the two worldviews.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teachers are unable to integrate science and IK because they are not specifically trained specifically to do so.</td>
<td>14</td>
<td>39</td>
</tr>
<tr>
<td>Without my exposure to SIKSP I could never have thought that the integration of science and IK was possible</td>
<td>19</td>
<td>27</td>
</tr>
<tr>
<td>Seminars, lectures and workshops helped me understand argumentation as a teaching strategy.</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td>Having experienced SIKSP, I can say that argumentation can lead to positive or negative controversies in class.</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>The SIKIPS lacks continuity on tasks covered in order to conclude tasks undertaken</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>I now embrace the science-IK curriculum and believe it could motivate learners to participate actively in class.</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Sub-total</td>
<td>70</td>
<td>100</td>
</tr>
</tbody>
</table>

Q. 5a: Based on your experience over time, what abilities do you consider critical to your participating in argumentation?

<table>
<thead>
<tr>
<th>Abilities</th>
<th>33</th>
<th>42</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers' knowledge and understanding of the nature, role and process of argumentation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teachers' competency to develop argument-based lesson plans</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Teachers' ability or self-efficacy (i.e. the ease and confidence) to teach an argument-based lesson</td>
<td>35</td>
<td>44</td>
</tr>
<tr>
<td>Learners’ Knowledge and understanding of the process of argumentation</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Sub-total</td>
<td>79</td>
<td>100</td>
</tr>
</tbody>
</table>

Q. 5b: What factors have you found to facilitate or hinder the development of such abilities?

<table>
<thead>
<tr>
<th>Factors that facilitate</th>
<th>f</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers who are well trained in both content and argumentation skills</td>
<td>16</td>
<td>38</td>
</tr>
<tr>
<td>Ability to manage diversity, group work and scaffold argumentation practically</td>
<td>11</td>
<td>26</td>
</tr>
<tr>
<td>Creativity on the part of teachers</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Availability of materials</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Teachers’ willingness to embrace change</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Learners with considerable knowledge of content and argumentation</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Sub-total</td>
<td>42</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factors that hinder</th>
<th>f</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time constraints due to examination-driven curriculum</td>
<td>9</td>
<td>22</td>
</tr>
<tr>
<td>Inadequate knowledge of content and/or argumentation skills</td>
<td>16</td>
<td>39</td>
</tr>
<tr>
<td>Teacher resistance to change</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>Large classes, dominance of the scientific worldview, cultural or second language related problems, etc</td>
<td>12</td>
<td>29</td>
</tr>
<tr>
<td>Sub-total</td>
<td>42</td>
<td>100</td>
</tr>
</tbody>
</table>

Q2a asks: “In what ways have your experiences in the SIKSP or related activities (modules, seminars and workshops) informed the way you frame (i.e. bring coherence to, or make sense of the experiences) you have acquired in terms of the way you construed the controversial issue of integrating science and IK at the time you started participating in the activities,
during the period of your involvement, and now?” Q2b asks: “Were you once opposed to the new curriculum? If yes, why? If not, why not. Have you changed your view over time and if so how?”

Dipu, a 50 year-old physical science teacher with an engineering background and who had taught for 12 years after about 20 year-stint in the oil industry said: “Having gone through all the course work, workshops and seminars, I came to understand [emphasis] that without the understanding of the NOSIKS [nature of science and IKS] and argumentation, which from the historical and philosophical perspective of science, it would be almost impossible to integrate the two.” He added that, “IK was not just knowledge of the past, but many people are still using it nowadays and hence is just knowledge which is authentic to a particular people’s experiences and by no means inferior to present day technologies.”

Dana, a Black 51 year-old physical science teacher with over 20 years of teaching experience, said, “I think that my participation in the SIKSP and the research in the schools have made me to see [emphasis] that it is possible to teach both science and IK in an atmosphere of mutual trust and discussion where IK is respected and not negated or downgraded.” Rhoda, a still active 68 year-old White teacher trainer with about 41 years of teaching experience said, “In my own teaching with pre-service educators, before my retirement, my attempts at integrating IK according to the dictates of the curriculum were more of the nature of adding on anecdotal information about cultural practices that could be linked to modern science practices. The IK information that emerged from argumentation exercises during workshops gave quite a different perspective…”

Diamond, 47 year-old Mathematics teacher trainer with 22 years of teaching experience indicated that: “The workshops which I have attended have, in a lot of ways, helped me to move away [emphasis] from the idea that IKS is not concrete knowledge which can be tested and validated. There has been talk among teachers that IKS is associated with myths and witchcraft and that there was no way science and IKS could co-exist.” Rosalind, a 34 year-old physical science teacher with 13 years of teaching experience stated that: “My experiences in the SIKSP activities have reformed my way of thinking [emphasis], doing things completely. When I started I did not appreciate indigenous knowledge nor did I realize its richness until [emphasis] I matured in these workshops.”

Liz, a 51 year-old grade 3 teacher with 34 years of teaching experience, contended that: Before the [emphasis] workshops I thought that Western Science is dominant over IKS. Western Science is the only science that can heal people. In my view IKS was all about witchcraft…” Salome, a 44 year-old doctoral student and teacher trainer with 18 years of teaching experience said: “The first time I participate in the SIKSP project the concept of IK and IKS were new to me. To be frank I did not even hear about them and obviously I could not think about integrating science with Ik in school system.”

Esther, a 45 year old teacher trainer with 25 years of teaching experience stated that: “Being involved with SIKSP has been an inspirational journey. The fact that the group is heterogeneous (students and lectures with different perspectives and knowledge about teaching IKS) has provided a very rich environment for sharing knowledge and feelings about IKS. I was a bit apprehensive about the duel interrogation of both scientific and IKS concepts but after attending the workshops and reading considerably on IKS and nature of science, I came to regard both as equipollent. I have to holistically and critically analyze concepts so that I don’t dichotomize them.

In terms of whether or not the subjects were opposed to the new inclusive curriculum Dipu said, “Yes, I had felt that there was more emphasis on detailing and recording of what one is going to do, have done and that there was no time for doing the actual job of teaching...Although I still feel that the new curriculum implementation was introduced without proper preparation–I do feel that the content or its approach is a good one which
requires drastically different teaching and learning approaches and that more should be invested in teacher training...” Dana, on the other hand said, “I was not opposed to the clause of science-IK integration, but thought it was an attempt to include other views other than those of the West in science to indicate that the apartheid era had indeed past but [emphasis] as I began reading, I realized that it was not just a South African issue, but a world-wide perception.”

Kalpatrick: a 61 year-old teacher trainer with 38 years of teaching experience stated that, “I was not much concerned about the Indigenous knowledge in Sciences at first, but since I have joined the SIKPS programme, I obtained more knowledge about IKS. Currently, I am fully convinced that Sciences and IKS need to be integrated and recognition need to be given to lost knowledge in order to emphasize on the importance of values...I am also the one who is advocating the importance of integrating IKS and Sciences in my field of work. I also took part in screening text books and always was looking for the cultural aspects in topics.

According to Rhoda, “I was never against the integration of indigenous knowledge into the science curriculum. I grew up with a familiarity with many cultural practices embedded in African storytelling and through interacting with children in the farm environment in which I grew up...With the insight gleaned from SKISP [emphasis] workshops particularly argumentation exercises my approach would be different.” Dipu added that “At the beginning ...I felt that IKS and science where two different knowledges and that it was almost impossible to combine the two.” Diamond said, “However, I believe that during teaching and learning science IKS [emphasis] could be used to explain some science concepts from a socio-cultural point of view... Yes. I knew the (outcomes-based) curriculum had failed in the USA and Australia, so somehow I thought it was going to fail in South Africa. In addition, I also realized the teachers were not ready for this type of curriculum especially the section where the integration of science and IKS is required. I still feel teachers need to be professionally developed on how to integrate science and IK.”

Salome stated that, “During my participation I start[ed] to make sense [emphasis] of the concept IK and IKS practices-its importance...” Rosalind said,” I have now reached a level where I am confident [emphasis] of integrating these two worldviews harmoniously...” Liz adds, “After attending the workshops I realized that IKS is not something new to me, perhaps the terminology. I grew up in a multicultural house...Yes, I was in opposition towards the new curriculum...but after the Science-IKS curriculum was unpacked, I tried to convince myself that this curriculum can work if teachers are trained properly...”

The common themes resonating through the excerpts above reveal discernible perceptual shifts and belief revision among the subjects which range from opposing, cautious, to supporting stances of the subjects towards an indigenized curriculum thus corroborating earlier studies that have shown the effectiveness of argumentation for bringing about increased understanding, changes in people’s worldviews and professional practice (e.g. Author, 2004, 2007a & b, 2011; Ebenezer, 1996; Erduran et al, 2004; Simon et al 2004; Skoumios & Hatzinikita, 2009 ) to a state where they have become favourable disposed to the implementation of the new curriculum as a result of their experiences in the SIKSP (e.g. Author, 2004, 2005, 2006, 2007a & b; Author & Associates, 200a & b).

It is important to point out that the use of conjunctions in phrases or sentences e.g. but, since, however, now, before, after, “with insight gleaned from,” “make sense of,” “came to understand,” “IK was just not knowledge of the past but many people are still using it,” “have made me to see,” “have reformed my way of thinking,” “This realization convinced me,” “have now reached a level where I am confident,” “My understanding grew...,” “after attending the workshops,” “SIKSP has been an inspirational journey. I now appreciate my socio-cultural attributes and also view them as essential for my day to day life.” “I do feel
that the content or its approach is a good one,” “gave quite a different perspective,” “After my experiences in the SIKSP I now began reflecting on the practices of my people and saw that many of them were in fact congruent with science,” and like phrases are indicative that perceptual shifts or belief revision have occurred. On the other hand, a lack of perceptual shift or belief revision among the subjects is implied by such statements or phrases such as: “I still feel that teachers need,” even after participating in the SIKSP’s lectures and workshops and related activities.

Conclusion
Whatever arguments can be raised concerning the subjects’ reflective diaries (experiences) on the SIKSP, there is sufficient evidence to show that their overall stances towards the new curriculum have changed over time as a result of participating in the project thus confirming the potential of argumentation in knowledge building or belief revision (e.g. Erduran et al, 2004; Leitao, 2000). Further, the changes in their views reflect some elements of both the Piagetian personal constructivist as well as the Vygotskian social constructivist notions of conceptual change (Leitao, 2000) perhaps as a result of their involvement in intra- and inter- and trans-argumentative transactions of the SIKSP particularly in their pursuit of consensus or cognitive harmonization (Author, 2007a & b; Berland & Lee, 2012). Their reflective diaries or appraisal of experiences on SIKSP seemed to suggest a perceptual shift towards the new curriculum (Leitao, 2000) which otherwise might have been different. The findings have also corroborated Fenstermacher’s assertion that empirical inquiries would be extremely useful for determining how and why changes take place in teachers’ practical arguments” (Ebenezer, 1996). It has also gone beyond identifying the subjects’ practical arguments by tracing the changes in their thinking about their instructional practices. The implications of the findings for teacher training, curriculum development and instructional practices in terms of shifting from the transmission to the discursive or argumentative mode of instruction are certainly worthy of closer scrutiny.

References
Author 2004, 2007a & b, 2011; Author & Associate, 2008 a & b.
Knowledge production of indigenous technology: learners’ understanding of their context

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Abstract

Indigenous technology can be employed by the native inhabitants of the country and it constitutes an important part of their cultural and should therefore be protected against exploitation by industrialized countries. The purpose of this study was to investigate learners’ awareness of indigenous technology that is produced in their community. The participants of the study were 90 learners from grades 8-12 from Tshwane West districts who were conveniently selected. The study used questionnaires to collect data which was designed to measured learners’ awareness of indigenous technology. The data was analysed using SPSS software to obtain frequency distribution on the aspects of indigenous technology. The paper
employs the conceptual framework of “knowledge production”. The findings indicated that most of the learners seem to be aware of the term ‘indigenous technology’ which means that the level of their knowledge production was more orientated toward technology produced in their context. However, there is still a need to teach them how this knowledge can be used, protected and passed on in order to benefit them as well as the community around them. There is a need for further study to understand the depth of knowledge they hold in indigenous technology. The findings of this study can help the department of education as well as university to further provide training to teacher on how indigenous technology can be utilised and protected in order to improve our economy.

Introduction
Indigenous technology plays an essential and practical role in the development of economy. Indigenous knowledge has a very big impact in the economic growth of the country as the scientists and technologist can utilise it to improve the life of people. The inclusion of indigenous knowledge in the South African curriculum is significant as it promotes the visibility of indigenous technology. Indigenous technology is the specific contextual knowledge that has been previously used and transferred to meet human’s needs or to solve problem. New South African curriculum has introduced Technology as a subject and included indigenous technology and culture as a component of learning (DoE, 2002). The inclusion of indigenous knowledge in the curriculum statements enable educators to recognise different knowledge systems that coexist and understand that they can complement or conflict each other (Vandeleur, 2010).

In a South African context, indigenous knowledge has historically been transformed to become both a tool of oppression and a voice within the struggle for liberation (Jansen, 1999). The transformation of South African curriculum recognizes indigenous knowledge and it is included as an element of learning in the curriculum (DoE, 2002). As stated earlier, Technology Education was one of the subjects that include indigenous technology and culture as a component of learning. Breidlid (2003) explains the inclusion of indigenous knowledge elements in the curriculum as an attempt to contextualize the curriculum in a South African setting. Breidlid further adds that indigenous knowledge seems to arise from location of indigenous cultures in the midst of a modernist and market driven curriculum. However, the challenge for indigenous knowledge in South African education remains situated in a process of exploring new possibilities through a variety of projects and the establishment of initiatives (Turnbull, 2000). This includes the acknowledgement of indigenous knowledge in education and the reconstruction of sciences and technology curriculum.

This study investigates learners between grades 8 to grade 12. Therefore, the assumption is that all students have been exposed to this concept of indigenous technology during the period of learning in various subjects. In addition, all students who are in these grades have done science and technology as a subject and those subjects have the elements of indigenous knowledge. Therefore, a critical question to consider is that if this element of indigenous technology is included in the school curriculum how much knowledge do learners have on this concept?

Indigenous knowledge
Indigenous knowledge is an adaptable, dynamic system based on skills, abilities, and problem-solving techniques that change over time depending on environmental conditions (Flavier, de Jesus and Mavarro, 1995:11). Vandeleur (2010) argued that local knowledge is a practice that is developed by peoples with long histories of close interaction with the natural
environment. Indigenous knowledge is a thought about our local context and seeks to integrate the cultural or social events and the academic dimensions of natural science and technology education (Breidlid, 2003). Indigenous knowledge can be referred to as local knowledge which consists of different types of knowledge that the community has possession of and they know how and where it is utilised (Vandeleur, 2010).

By the mid 1990s the southern African region had seen a number of initiatives, which had sought to liberate indigenous knowledge processes from rhetorical debates and constraining definitions (Masuku & Neluvhalani, 2004). These developments contributed much on indigenous knowledge (IK) activities and debates within the southern African region (ibid). Indigenous knowledge is a broader component of knowledge that encompasses indigenous science and indigenous technology. Indigenous science and technology relate to both the science knowledge and technology knowledge of long-resident, usually indigenous peoples in the communities. Indigenous people are long residence who knows and practice history of the community (Vandeleur, 2010). Indigenous knowledge (IK) is a local knowledge that is unique to a given culture or society (Vandeleur, 2010). This knowledge can be seen as a basis for local-level which can be transferred to modern knowledge and enhance natural resource management in the field of agriculture, food preparation, health care, education, etc. Transference of indigenous knowledge is vital as it transfers this knowledge from generation to generation, through our words and practice.

Indigenous technology has a great impact in the current world. Indigenous technology constitutes an important part of citizen inheritance and should therefore be protected against exploitation by industrialized countries. The advantage of indigenous technology is that it can be used by the local residents for farming, good production of crops, increase fertility of soil, rise in quantity and quality of food, healing diseases etc. For example during National Science Week in North West, one of the schools invited some of the indigenous doctors to demonstrate indigenous knowledge. One of the indigenous doctors demonstrated to learners how they can heal themselves if they have flue using local herbs.

All residence in the community who participate in indigenous science irrespective of the duration may be thought of as specialists in local indigenous science (Godin & Gingras, 2000). Godin & Gingras explain ‘science as a corpus of conceptual knowledge and experimental methods that allow the investigation of objects pertaining to the natural or social worlds and body of knowledge derived from these investigations’ (ibid: p.2). Ogawa (1995) distinguish science into two level i.e. individual or personal science and cultural or societal science. Ogawa further explain individual or personal science as knowledge that is accumulate by individual person and cultural or societal science as knowledge that is accumulated by group of people who spend generations learning about life in one place. He Further explain indigenous science as “a culture-dependent collective rational perceiving of reality,” where “collective means held in sufficiently similar form by many persons to allow effective communication, but independent of any particular mind or set of minds” (ibid: p. 588). Agrawal (2002) describes indigenous science as the study of systems of knowledge developed by a given culture to classify the objects, activities, and events of its given universe. Indigenous science interprets how the local world works through a particular cultural perspective (Godin & Gingras, 2000). In conclusion indigenous science can be seen as the knowledge of both indigenous expansionist cultures and as the home based knowledge of long-term resident or resident peoples (ibid).

**Contribution of indigenous knowledge towards development of technology**
Technology is defined as the set of tools and machinery as well as the knowledge pertaining to their functioning and use (Godin & Gingras, 2000). Traditional peoples who are well equipped with knowledge of science and technology have contributed largely in the modern applied sciences such as medicine, architecture, engineering, pharmacology, agronomy, animal husbandry, fish and wildlife management, nautical design, plant breeding, and military and political science (Snively & Corsiglia, 2000). Traditional people tend to spend generations learning about life in one place (ibid). Similarly, Cruikshank (1991) indicated that indigenous knowledge is accumulated over a lifetime for example hunting peoples carefully study animal and plant life cycles, topography, seasonal changes and mineral resources and their conclusions about landscape, climate and ecological changes are usually based on their lifetime experience. Traditional people used an ideology of spirit to connect and communicate with different elements of nature. Furthermore, Similarly, Snively & Corsiglia (2000) argue that many indigenous people believe that all living things plant, animal, bird, or creatures of the sea are endowed with a conscious spirit and therefore can present themselves in abundance or not at all. Most of the people who were fisherman used many different prayers and songs to communicate with the spirit of the fish to achieve success in fishing (Emmons, 1991). Therefore, to what extend do learners understand indigenous knowledge in their society.

Learning through indigenous knowledge

The new curriculum (C2005) suggests that teachers must consider learners pre knowledge as they bring to the classroom ideas that are based on their context and cultural backgrounds (DoE, 2010). Thakadu (1997:99) argued that ‘indigenous knowledge should be a vital base and component in every subject matter, made possible by the fact that the holistic nature of indigenous knowledge gives it a broad spectrum of coverage in all spheres of life’. Teachers need to explore and integrate subject matter instruction with prior knowledge that learners bring to the classroom. Shava (2000) argue that educational approaches should be contextual and should encourage the learners to bring in and share their experiences in the learning situation. Ngwane (1999) conducted a study on the “socio-economic issues that had contributed to the decrease of plant species in Eastern Cape”. In her study she found that the lack of to integrating biodiversity in education in the rural area has a big impact on educational matter because textbook writers are not situated within the contextual realities. She further argued that the teaching of subject matter must be situated within the context of learners’ lives and experience (ibid). On the other hand, Masuku (1999) highlighted the importance and role of indigenous people in enriching the curriculum and help to incorporate contextual learning and re-conceptualization of schools in communities. Masuku further suggested that there is a need to bridge the gaps and provide space in schools for adults to interact with learners about indigenous environmental knowledge.

Teachers are faced with challenge to use indigenous knowledge as an initial point in a process of teaching a specific subject which is both transformative of and liberating for the cultural perspectives (Shava, 2000). In a South African context, new curriculum encourages teachers to listen to and take learners’ idea seriously so that they can build their lesson on what learners know (DoE, 2002). There are many South African literatures and other resources that have been done on indigenous knowledge that teachers can learn and prepare their lesson based on. for example in 1994 Bona magazine published an article on the way different South African people store grain and how it can be compared with the modern grain storing silos (Bona Magazine, 1984, cited in Masuku, 1999). Another study on “An investigation of environmental knowledge among two rural black communities in Natal” was conducted and focused on both indigenous knowledge and environmental education.
processes in Natal’s region (O’Donoghue, 1994). Asafo-Adjei (2004) explores teaching of “indigenous agricultural knowledge (IAK) in the school and community contexts”. The researcher used three wild vegetable plants, and found that the use of IAK in curriculum contexts is a practical process that involves a range of complex, often sensitive socio-cultural perspectives on agricultural practices and agricultural science. However, this practice has the potential to enrich, expose and enhance the learning of ‘traditional sciences’ in school contexts which foster situated learning. This opened up an interesting question on the amount of knowledge that learners have on contextual learning and indigenous knowledge.

Conceptual framework
This study used the concept of “knowledge production” which was prostituted by Gibbons, Limoges, Nowotny, Schwartzman, Scott and Trow (1994). Posch (2000) explains knowledge production as the utilisation of local knowledge, indigenous expertise and resources. Gibbons et al (1994) argue that fundamental transformation of knowledge production takes place outside of the existing academic disciplines. They further categorise knowledge production into two modes i.e. Mode 1 and Mode 2 (ibid). Mode 1 refers to the core or base of disciplinary and specialised knowledge. Mode 2 refers to the recognition and validation of the context in which such knowledge is produced (ibid). Kraak (2001: 2) in his study of “Globalisation, the learning society and the case for a unified national system of higher education in South Africa” adapted this concept of “knowledge production” (Gibbons et al., 1994). Kraak explains Mode 1 as knowledge produced within subject-specific disciplines and Mode 2 as knowledge produced essentially collaborative in its intentions and proves by far to be more heterogeneous in terms of learner inputs which do not always necessarily represent the views of the experts as contained in the final product. It is believed that Mode 2 knowledge production is essential and is a prerequisite for Mode 1 (van Wyk, 2002). In contrary, Kraak (2001) argues that these modes ought to become increasingly interdependent and reshape each other to enhance understandings of the interconnectedness of science and technology with all relevant social phenomena. Since there are dramatic changes occurring in virtually all disciplines in a rapidly globalised and shifting world, there has been a radical shift towards Mode 2 (van Wyk, 2002). This implies that for science and technology subjects, ‘new and appropriate knowledge could arise in the process of recognising the value of community involvement and the impact that the local context could have on knowledge construction in science and technology’ (van Wyk, 2002:2). This study adapts Mode 2 of knowledge production and it refers to learners’ awareness of indigenous technology in the context in which they live. Therefore, this paper investigated the awareness of learners of indigenous technology around their community. Learner’s awareness of indigenous technology was explored on the following aspects i.e. learners’ awareness of term indigenous technology; history of Indigenous technology; Importance of indigenous technology; Interest about learning indigenous technology; Promotion of indigenous technology; Knowing about traditional medicine; and Understanding fermentation about process in making traditional beer. These aspects were used to investigate and were used as categories to analysed data on learners’ awareness of indigenous technology.

Methodology
This study is a quantitative research (Bernard, 2011). The participants were conveniently selected from ninety (90) schools in Tshwane West districts. Participants were school learners ranged from grades 8-12. Learners were given letters to give to parents so that they can allow them to participate in National Science Week. The letter was given to the schools so that they can make copies and give learners. Data was collected using questionnaires to measure learner’s awareness of indigenous technology production within their context.
Statistical Package for the Social Science (SPSS) software was used to analyse data reporting on frequency distribution on learners’ responses per grades in various aspects of indigenous technology. The variables that were measuring learners’ awareness of technology were identified from the questionnaire and were captured into spreadsheet which was later imported to SPSS programme. Then the programme was used to obtain frequency distribution of learner’s awareness of indigenous technology in different grade. The purpose of the study was to investigate the extent to which learners are aware in the area of indigenous technology. Therefore the study opted to use frequency distribution as a technique to measure their awareness.

Results and discussion

Table 1: Learners distribution per grade

<table>
<thead>
<tr>
<th>Grade</th>
<th>Frequency</th>
<th>Percent</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 8</td>
<td>5</td>
<td>5.6</td>
<td>5.6</td>
<td>5.6</td>
</tr>
<tr>
<td>Grade 9</td>
<td>3</td>
<td>3.3</td>
<td>3.3</td>
<td>8.9</td>
</tr>
<tr>
<td>Grade 10</td>
<td>8</td>
<td>8.9</td>
<td>8.9</td>
<td>17.8</td>
</tr>
<tr>
<td>Grade 11</td>
<td>64</td>
<td>71.1</td>
<td>71.1</td>
<td>88.9</td>
</tr>
<tr>
<td>Grade 12</td>
<td>10</td>
<td>11.1</td>
<td>11.1</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>90</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 illustrates the frequency distribution of learners per grades. Nearly three quarter (71.1%) of learners were from grade 11 classes, followed by less than quarter (11.1%) from grade 12. The other learners were from grade 8 (5.6%), grade 9 (3.3%) and grade 10 (8.9%).
Table 2. Breakdown of learners school grades and awareness of indigenous technology

<table>
<thead>
<tr>
<th>Awareness of indigenous technology</th>
<th>Learners school grades</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grade 8</td>
<td>Grade 9</td>
</tr>
<tr>
<td>Strong agree</td>
<td>0 (0.0%)</td>
<td>1 (33.3%)</td>
</tr>
<tr>
<td>Agree</td>
<td>3 (60.0%)</td>
<td>1 (33.3%)</td>
</tr>
<tr>
<td>Neutral</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Disagree</td>
<td>1 (20.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Strong disagree</td>
<td>1 (20.0%)</td>
<td>1 (33.3%)</td>
</tr>
<tr>
<td>Total</td>
<td>5 (100%)</td>
<td>3 (100%)</td>
</tr>
</tbody>
</table>

Statistical analysis was done to analyse the breakdown of learner’s responses on some variable of indigenous technology with the aim to understand their response per grades. It can be seen from table 2 that most learners were from grade 11. Out of all the learners from grade 11, nearly three quarter (70.3%) of them agreed that they are aware of term indigenous technologies. Only a handful (10.9%) of learners from grade 11 indicated that they are not aware of the term indigenous technology. More than a handful (18.8%) of them was neutral about being aware of indigenous technology. It could be interpreted from the table that most of learners from grade 11 are at higher level than those in grade 8, and 9 and 10. Few learners were from grade 12, and half (50%) of them agreed that they are familiar with term ‘indigenous technology’. Just less than half (40.0%) of learners in grade 12 were neutral about being aware of indigenous technology, which is surprising because it was supposed to be lower number compared learners from other grades.

Table 3. Breakdown of learners grades and knowledge of traditional medicine

<table>
<thead>
<tr>
<th>Knowledge of Traditional medicine</th>
<th>Learners school grades</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grade 8</td>
<td>Grade 9</td>
</tr>
<tr>
<td>Strong agree</td>
<td>2 (40.0%)</td>
<td>2 (66.7%)</td>
</tr>
<tr>
<td>Agree</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Neutral</td>
<td>1 (20.0%)</td>
<td>1 (33.3%)</td>
</tr>
<tr>
<td>Disagree</td>
<td>2 (40.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Strong disagree</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Total</td>
<td>5 (100%)</td>
<td>3 (100%)</td>
</tr>
</tbody>
</table>

Learners were asked to respond to degree of their agreement/disagreement with aspects related to knowledge of traditional medicine used to cure flu and colds per grades. It was important to check the relationship between learners’ grades and the extent of their agreement and disagreement knowing traditional medicine that cure flu and colds. Again, as in the previous table it is clear from table 3 that most learners were from grade 11. Out of all the learners from grade 11, just more than half (51.5%) of them agreed that they know traditional medicine that cure flu and colds. More than one quarter of (29.7%) of learners from grade 11 indicated that they know traditional medicine to cure flu and colds. More than a handful (18.8%) of them from grade 11 were neutral about knowing traditional medicine. When looking across the grades it seems most of learners (66%) from grade 9 agreed that they know traditional more than those in grade 11. However, looking very closely it is clear that they were only few learners (2) out of 90 learners in grade 9 as compared to grade 11. There were few learners from grade 12, and less than half (40%) of them agreed that they know traditional medicine for curing flu and colds. Only few (20%) of learners from grade 12 do
not know traditional medicine for curing flu and colds, while 20% of them were neutral about knowing the traditional medicine.

Table 4. Breakdown of learners school grades and understanding of fermentation process

<table>
<thead>
<tr>
<th>Understanding fermentation process</th>
<th>Learners school grades</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grade 8</td>
<td>Grade 9</td>
<td>Grade 10</td>
<td>Grade 11</td>
<td>Grade 12</td>
</tr>
<tr>
<td>Strong agree</td>
<td>2 (40.0%)</td>
<td>1 (33.3%)</td>
<td>1 (12.5%)</td>
<td>11 (17.2%)</td>
<td>3 (30.0%)</td>
</tr>
<tr>
<td>Agree</td>
<td>1 (20.0%)</td>
<td>1 (33.3%)</td>
<td>1 (12.5%)</td>
<td>8 (12.5%)</td>
<td>1 (10.0%)</td>
</tr>
<tr>
<td>Neutral</td>
<td>2 (40.0%)</td>
<td>0 (0.0%)</td>
<td>3 (37.5%)</td>
<td>21 (32.8%)</td>
<td>4 (40.0%)</td>
</tr>
<tr>
<td>Disagree</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>11 (17.2%)</td>
<td>2 (20.0%)</td>
</tr>
<tr>
<td>Strong disagree</td>
<td>0 (0.0%)</td>
<td>1 (33.3%)</td>
<td>3 (37.5%)</td>
<td>13 (20.3%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Total</td>
<td>5 (100%)</td>
<td>3 (100%)</td>
<td>8 (100%)</td>
<td>64 (100%)</td>
<td>10 (100%)</td>
</tr>
</tbody>
</table>

Table 4 shows the extent to which learners from each grade agreed or disagreed that they understand fermentation process used to make traditional beer such as Amarula and Mbamba. Once again learners from grade 11 were more than other grades. About 37.7% of learners from grade 11 disagreed that they understand fermentation to make traditional beer as compared to 29.7% who agreed that they know fermentation to make traditional beer. From grade 12 learners 40% of leaners agreed that they understand fermentation process to make traditional beer compared to only 20% who don’t understand fermentation process used to make traditional medicine. The frequency distribution from grades 8, 9, and 10 of those who agreed that they understand fermentation process for making traditional beer are 60%, 66% and 25% respectively.

Table 5. Frequency distribution of learners on aspects of indigenous technology (n =90)

<table>
<thead>
<tr>
<th>Aspect of indigenous technology</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Awareness of term indigenous technology</td>
<td>31.1%</td>
<td>37.8%</td>
<td>80.9%</td>
<td>4.4%</td>
<td>7.8%</td>
</tr>
<tr>
<td>Indigenous technology is about historically excluded technologies</td>
<td>20.2%</td>
<td>23.6%</td>
<td>23.6%</td>
<td>15.7%</td>
<td>16.9%</td>
</tr>
<tr>
<td>Importance of indigenous technology</td>
<td>52.8%</td>
<td>33.7%</td>
<td>9.0%</td>
<td>2.2%</td>
<td>2.2%</td>
</tr>
<tr>
<td>Interest about learning indigenous technology</td>
<td>66.3%</td>
<td>18.0%</td>
<td>6.7%</td>
<td>4.5%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Promotion of indigenous technology</td>
<td>40.4%</td>
<td>36.0%</td>
<td>14.6%</td>
<td>4.5%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Knowing about traditional medicine</td>
<td>27.0%</td>
<td>25.8%</td>
<td>16.9%</td>
<td>12.4%</td>
<td>18.0%</td>
</tr>
<tr>
<td>Understanding fermentation about process in making traditional beers</td>
<td>19.1%</td>
<td>13.5%</td>
<td>33.7%</td>
<td>14.6%</td>
<td>19.1%</td>
</tr>
</tbody>
</table>

Learners were asked to respond to degree of their agreement/disagreement with aspects related to awareness, knowledge and importance of indigenous technology within their
context. Table 5 shows that more than three quarter of learners (84.3%) said they had interest in learning indigenous technology. This was in-line with Department of Science and Technology (DST, 2005) campaign that was design to promotes awareness, debate, and production of indigenous knowledge and technologies in South Africa. In a study conducted by Vandeur (2010), teachers were interested in learning more about indigenous technology after they have gone through the workshop about integrating indigenous technology in their lessons. This is not surprising as it is shown in the table that majority of learners (80.9%) were neutral on awareness of the term indigenous technology, partly due to not been taught indigenous technology in the classroom. It is also not surprising to see that most learners (33.7%) indicated 'neutral’ combined with those who disagreed on understanding fermentation process. This shows that most learners are still lagging behind with regard to awareness and knowledge of indigenous technology. Most learners (43.8%) also agreed that indigenous technology is historically excluded technology as compared to those (32.6) agreed, which is not very surprising given South African historical context. The fact that learners does not have an appropriate awareness and knowledge of indigenous technology can signify teachers having difficulties with the interpretation of this aspect in the curriculum as well as a lack of meaningful teaching and learning for various reasons (Vandeur, 2010).

**Validity and reliability**

Validity refers to the degree to which a measuring instrument has actually measure what it is designed to measure (Field, 2009). In this study questionnaire were used to understand learner’s awareness of indigenous technology. During analyses questions were used as categories in order to answer the research question. According to the finding the instrument was able to help the researcher to answer the research question. For example questions like “learners’ awareness of term indigenous technology; history of Indigenous technology; Importance of indigenous technology; Interest about learning indigenous technology; Promotion of indigenous technology; Knowing about traditional medicine; and Understanding fermentation about process in making traditional beer” enable the researcher to investigate learner’s awareness of indigenous technology.

Reliability tests if whether an instrument can be interpreted consistently across different situation (Goodwin, Holmes, Cochrane & Mason, 2003). Reliability of the study can be done though different methods: the test-retest method, alternate forms, internal consistency, and inter-scorer reliability (ibid). In addition, each method provides evidence for the responses to check if they are consistency. Not all of these methods are used for all tests. Therefore, this study used inter-scorer reliability. Inter-scorer reliability is the method that measure degree of agreement between two or more scorers, judges, or raters (Bernard, 2011). Other names for this type of reliability are inter-rater reliability or inter observer reliability (ibid). This type of reliability is often used when scorers have to observe and rate the actions of participants in a study (ibid). This research method reveals how well the scorers agreed when rating the same set of things (Bernard, 2011).

The reliability of this study lies on the number of learners on each rating i.e. strongly agree, agree, neutral, disagree and strongly disagree. If most learners are rated under strongly agree and agree, the interpretation was that they are aware of indigenous technology in that category. If most of the learners are rated under disagree and strongly disagree, the interpretation was that they are not aware of indigenous technology in that category. Therefore when looking at the overall interpretation of data in table 5, all categories indicated that most of the learners are aware of indigenous technology. Then the findings of this study can be regarded as reliable, particularly when looking at the purpose of the study.
Conclusion

Indigenous technology has a great impact in the current world as it is the treasure and inheritance of the community in which it was invented. Therefore, it is important for youth to know and understand the part of their cultural in-heritage so that they can protect it against exploitation by industrialized countries. As stated earlier, in this paper “knowledge production” and it refers to learners’ awareness of indigenous technology in the context in which they live. By assuming that learners who are neutral they are not sure about what to say, we will consider and combining extreme response i.e. (strongly agree and agree) as well as (disagree and strongly disagree). Therefore, the conclusion of this study will be based on the combination of those two responses. When looking at learners’ awareness, the data indicated that most of the learners in all grades are more aware about the term technology. This indicates that the introduction of Technology as a subject has a big impact on making learners aware. In terms of learners’ knowledge about traditional medicine the data indicate that most of the learner (47%) are knowledgeable about traditional medicine that can cure flu whereas only (27%) of learners indicated that they don’t know those traditional medicine. Looking at learners understanding of fermentation process, the findings show that the understandings of the learners in this element are equal (50%). Therefore, most of the learners seem to be aware of this term indigenous technology which means that the level of their knowledge production was more orientated. However, there is still a need to teach them how this knowledge can be used to benefit themselves as well as the community around them. There is a need for further study to understand the depth of knowledge they hold in indigenous technology.

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Moving classroom practices beyond the positivist view of scientific knowledge construction

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Abstract
This paper develops a case for moving classroom practices from the positivist view to the socio-constructivist view of scientific knowledge construction. Beginning with a review of literature on the generation of scientific knowledge claims through the lenses of the positivist and socio-constructivist viewpoints, the paper discusses how both views influence the perspectives in science education and instructional practices. Our contention in the paper is that argumentation is an effective rhetorical tool for discourse particularly with respect to socio-scientific issues which impinge on our sensibilities far beyond the confines syllogistic arguments, empiricism or positivism. In the same vein, the paper addresses different forms of arguments and dialogues that have potential for improving the teaching of argument in science. We see critical discourses as a form of persuasive or rhetorical dialogue and scientific inquiry as a type of inquiry dialogue that scientists deploy to buttress their claims. Further, it is our view that in the pursuit of knowledge building classroom discourses should reflect the two forms of dialogues as well.

Introduction
Studies on scientific knowledge construction and evaluation show that although positivists and social constructivists attempt to account for the generation of scientific knowledge claim, their views differ in many ways (Bauer, 1992; Cole, 1992; Duschl, 1988). Among others, their views on knowledge building have influenced the focus and perspectives of science education in general and instructional practices in particular. Science in schools is commonly portrayed from a positivist perspective as a subject in which there are clear right answers and that data normally lead unequivocally to an inconvertible agreeable conclusion (Driver, Newton, & Osborne, 2000, p.288). This practice has failed to empower students with the ability to critically examine the socioscientific issues that confront them in their everyday lives.

In the last few decades, however, various practical initiatives have been taken to promote changes in teaching that have broaden the perspective and function of science education from the narrow positivist perspective to a socio-constructivist and contextual point of view (e.g., Hunt, 1994; Solomon &Aikenhead, 1994; Solomon, Duveen, & Scott, 1992). This has resulted in the production of a variety of relevant curriculum materials. However, despite such imaginative initiatives, the dominant view of science, currently portrayed in most of our schools is still reflecting a basically positivist view of science in which the book of nature is read by observation and experiment (Driver, et al., 2000). There is overwhelming evidence from different kinds of sources that instructional practices that promote students engagement in learning tasks through collaborative dialogues have not taken root in classrooms (SMICT Study, 2005).

In view of the above fact (Driver et al., 2000; Duschl, 2007) contend that if science education is to help young people engage with the claim produced by science-in-the-making, it is necessary to reconceptualise the practices of science teaching so as to portray scientific knowledge as socially constructed. This change in perspective has major implications for pedagogy, requiring discursive activities, especially argument, to be given a great prominence (Driver et al., 2000; Kuhn, 2010). In this regard, we contend that such a strategy is critical to
moving classroom discourses from the positivist view of science towards the view of science as social process of human enterprise. We also argue that the scientific knowledge constructed in a social context of science classrooms through dialogic argument is potentially more useful than the knowledge constructed through recall of facts with confirmatory explanation surrounding socioscientific dispute. Such practices could produce students who could take part in resolving political, social, and professional controversies in their community.

Studies on students’ argumentation, particularly on science related issues, show that social dimensions influence argumentation (Grace, 2005; Kolsto, 2006; Mercer, 2000; Solomon, 1992). The assertion that argumentation has social aspect (Jimenez-Aleixandre, 2008, p. 118.) coupled with the view that learning through dialogical argumentation (which is part of the goals of constructivist science classroom) is grounded on socio-constructivist view of learning (Jimenez-Aleixandre, 2008, p. 93); guided this paper to situate its theoretical framework within socio-constructivist theory of argumentation.

**Implications of the positivist view of scientific knowledge construction for science teaching**

The theory of construction of scientific knowledge has been examined traditionally through positivist lenses (Urban Planning Blog, 2007). Positivists see science as an empirical process, where claims to truth are grounded in observation (Driver et al., 2000) and where conclusions are seen to be unproblematic deductions from such observations. For the same reason, (Longino, 1983, 1990) provided an insightful analysis on the view of positivists and shown how they rely on objective observations of individual scientists who abide by the constitutive values of science that determine what constitutes acceptable scientific practice. To positivists the core belief is constituted by the verifiability of facts by empirical observation of reality (Burbules& Linn, 1991). Positivists suggest a reliable way of evaluating scientific knowledge claims exists: just evaluate the science itself using a set of agreed upon standards that have been constructed by the scientific community (Bingle& Gaskell, 1994).

A variety of writers have argued in recent years that a positivist view of scientific knowledge is no longer warranted in education (Aikenhead, 1885; Burbules& Linn, 1991; Millar and Driver, 1987). Many of them (e.g., Bingle& Gaskell, 1994) have highlighted the limitations of positivist’s perspective in terms of their inherent views concerning the nature of scientific knowledge. Others indicated how the positivist view of scientific knowledge has dominated the field of science teaching for nearly a century till the late 20th century. For instance, Nelson (1998) explicates that the image of science presented in traditional science classrooms is the reflection of positivist view in which students are instructed to learn facts, memorize answers, and read text. Driver et al. (2000) add that the positivist view of science puts emphasis on the memorization of a collocation of facts at the expense of conceptual development. It focuses on confirmatory experiments, denies the role of the historical and social accounts of science, and presents science as a linear succession of successful discoveries.

Despite the various initiatives in the field of science education, the emphasis is still on what should be believed in rather than why something should be believed. In other words, the discursive exploration of scientific ideas, their implications and their importance are absent even after the introduction of the learner-centred curriculum. According to Donnelly, Buchan, Jenkins, Laws and Welford (1996) even the more recent introduction of the investigative work, is still interpreted in formulaic ways and has still failed to transcend the fallacy that there is a singular “scientific method”—the belief that science has been the result of the consistent application of a simple set of rules to every situation as it arose. Such practices are common even today in most science classrooms as these approaches to science teaching relay
heavily on the view of positivist and tend to reflect the way the positivist view the nature of science. Such a limited perspective inhibits opportunities for students to gain insight into the processes of knowledge construction in science.

The concept paper for rapid transformation of education system in Eritrea and the Revised Science Curriculum in South Africa and indeed many African countries reveal that science students and graduate of science are unable to provide evidence and justification to their claims when discussing or critiquing ideas (Government of Eritrea, 2002; Ogunniyi, 2004, 2007a & b). In view of this, it seems that we need to move classroom practices away from what Bloome, Puro and Theodorou (1989) call procedural display activities. The authors describe procedural displays as social habits of life in classroom that are enacted without question and often without a purpose to the students. In their seminal article “Doing the lesson or doing science: Argumentation in high school genetics” (Jimenez-Aleixandre, Rodriguez &Duschl  2000) identified two distinct purposes of applying the concept of procedural display to science classroom. The first purpose is, to fulfil expectations what students and teachers do while in school (e.g., review homework assignments, take lecture notes, take tests and complete lab activities). These sets of actions or procedural displays that make up the routines and ritual of doing science was found to be an obstacle to the enhancement of scientific dialogue or argumentation in science classrooms. The second purpose of procedural display is to provide a learning environment that both promote and facilitate students’ construction, representation and evaluation of knowledge claims and investigative methods.

From the forgoing, we contend that to move classroom practices beyond positivist view of science, the practices of science teaching should emphasis on the latter purpose of the procedural display. To attain such a goal, one needs to consider the views of social constructivist as an alternative theory for knowledge construction in order to (a) unpack the social aspect of science and (b) explore the social process of knowledge building practised in science and science related issues.

**Implications of the socio-constructivist view of science for science teaching**

As a preamble to this section it is important to note that the shift in position, that is, from the positivist to the socio-constructivist view, has been towards a view of science as a social process of knowledge construction that involves conjecture, rhetoric and argument (Taylor, 1996). This perspective recognizes that observations are theory-laden (Kuhn, 1992) and therefore, it is not possible to ground claim for truth in observation alone. Rather, claims are seen to be grounded through the process of argument. Appreciating the social process of knowledge construction, Bingle& Gaskell (1994) Kolsto and Ratcliffe (2008) and Urban Planning Blog (2007) indicate that in social constructivism consensus formation is not a process of validating a fact produced by an individual, rather it is a process of constructing a fact through a process of social negotiation.

Several authors (e.g. Cole, 1992; Latour, 1987) have made distinction between different forms of scientific knowledge. Latour (1987) expresses this distinction in terms of ready-made science and science-in-the making. He further argues that ready-made science is one in which what is conveyed is taken for granted and seen as uncontroversial and unrelated to the specific context of its development. Whereas science-in-the-making is the science currently been done every day in the laboratory and debated in public forums which are influenced by the cultural values of the individual and social group.

Arguing for the second form (i.e., of science-in-the-making ) of scientific knowledge, Driver et al. (2000) and Longino (1983, 1990) contend that whereas we assume that the natural world exists and has consistent properties, we do not have direct access to that world, and hence, our knowledge of it is constructed. Knowledge, therefore, is a human construction and
scientific knowledge as a social construction is thus provisional. Hence, establishing a knowledge claim in science, therefore, involves more complex processes than making generalizations from observations of the world through induction. This assertion is in sharp contrast with the view of positivist who claim that scientific knowledge is based in quantitative analysis and evidentiary based studies that rely on human observation to prove or disprove theories or statements of facts. However, when science is construed in the socio-constructivist terms the gradual development of knowledge through discursive activities; especially argument is given a greater prominence (Driver et al., 2000).

Argumentation in science classrooms
A conception of science as argument has come to be widely advocated as a frame for science education (Berland & Reiser, 2009; Bricker & Bell, 2009; Driver et al., 2000, Dushl, 2007; Jimenez-Aleixandre & Erduran 2008). Within this framework, various science educators have proposed the conceptions of science learning as argument (Kuhn, 1993; Duschl, 1990). Such a view of science learning has broader goals than just learning scientific content. Thus, a pedagogical emphasis on argumentation is consistent with general contemporary goals of education that seek to equip students with capacities for reasoning about problems and issues (Kuhn, 2010). Successful introduction of argumentation activities in learning contexts, therefore, involves extending teaching goals beyond the understanding of facts and concepts, to include an emphasis on cognitive and meta-cognitive processes, epistemic criteria and the reasoning (Simon & Richardson, 2009; Bricker and Bell, 2009). Current emphasis in the science classroom has brought into focus consensus-building as an important instructional strategy (Berland and Lee, 2012). In an article on “Establishing the norms of scientific argumentation in classrooms”, Driver et al. (2000, p. 287 & 309) developed a case for the inclusion and centrality of arguments in science teaching and learning in science. Ebenezer (1996), Erduran (2006), Ogunniyi (2007a) have also argued that the interactive classroom arguments and dialogues can help learners and teachers to clear their doubts, acquire new attitude and reasoning skills, gain new insights, make informed decisions and change their perceptions.

A plethora of studies have also shown the importance of engaging students in classroom talk, which can include procedural, observational, and explanatory discourses. Of these, the form of argumentation, or the coordination of evidence and theory to support or refute an explanation, a model, a predication, or an evaluation (Duschl & Osborne, 2002) might be considered to be among the most important epistemic tasks of science (Duschl & Osborne, 2002; Osborne, Erduran, & Simon 2004). In this perspective, argumentation is recognized as a central process through which evidence is used in the development of explanations and requires evaluation of explanations through the ways of knowing associated with the science community. Osborne et al (2004) have argued that argumentation is part of what might be called science discourse, which should be among the discourses present in a science classroom if the classroom is one in which knowledge is used as scaffold and for making sense of what is constructed in collaboration with peers. However, some forms of argumentation might be more important to science discourses than others. Thus, we need to look for an appropriate form of argument which could guide classroom practices towards teaching science as a social process.

Forms of arguments
As a framework for the discussion, we have used Van Eemeren et al (1996) concepts and forms of arguments. The focus is to explore different forms of arguments and identify those forms that are relevant to teach the social process of science. Van Eemeren et al (1996) identified three forms of arguments: analytical, rhetorical and dialectical. Analytical
argument is grounded in the theory of logic, proceeding from inductive or deductive claims and premises to a conclusion. However, Walton (1998) asserts that formal logic such as analytical argument is not adequate for describing argumentation in science. This is supported by Driver et al. (2000) who argue that analytical argument is irrelevant for inclusion in science teaching. Jimenez-Aleixandre, Rodriguez and Duschl (2000) complement the view of Walton and Driver et al indicating that the application of formal logic to the sciences represents the cornerstone of logical positivism. Such form of argument does not assist students to show that an argumentation discourse may embrace both logical and non-logical aspects of human experience. In view of the foregoing, analytical argument will not be further elaborated in the paragraphs that follow as they fail to promote the social norms of argumentation.

Unlike analytical argument, rhetorical and dialectical argument do not employ formal logic, rather they employ informal reasoning which are not necessarily illogical (Kolsto & Ratcliffe, 2008) but context based. The two forms of arguments have both individual or what Ogunniyi (2007a) calls intra-argumentation and a social meaning making which involves dialogues with others in small groups (inter-argumentation) or across groups (trans-argumentation). In other words, the individual meaning refers to any piece of reasoned discourse whereas the social meaning entails the dispute or debate between people opposing each other with contrasting sides to an issue (Billig, 1987). In this regard, Driver, et al (2000) seem to support the position of Billig (1987) and Ogunniyi (2007a). However, Kolsto and Ratcliffe, (2008) claim that all argumentation is basically social, as rhetorical arguments expect an audience.

The nature of rhetorical argument is different from dialectical argument. While rhetorical form of argument refers to arguments used in monological situations where an orator employ discursive techniques or rhetoric to persuade an audience; dialogical form of arguments are involved in dialogues involving two or more discusants (Jimenez-Aleixandre, Rodriguez, &Duschl, 2000; Kolsto & Ratcliffe, 2008). Rhetorical form of argument takes place when teachers marshals evidence and construct arguments for their students (Driver et al., 2000). Examples of rhetorical arguments are common in science lessons in which an authoritarian teacher provides a scientific explanation to a class with the intent of helping them to see it as reasonable (Duschl, 2007; Driver et al., 2000). According to Driver et al (2000) a rhetorical form of argument is one-sided and has limitations in educational settings. This is supported by Russell (1983) who provides an insightful analysis of teacher-led classroom discourse (authoritarian teaching) and showed how such discourse frequently relies on traditional authority and consequently, overlooks reasons and evidence. Watson, Lynch and Kuipers (2006) contend that that most of the small group discussions conducted in classrooms are of such kind and fail to establish the norms of scientific argumentation. Our experience in classroom practices indicates that most classroom discussions are teacher-led and the tasks framed by most science teachers neither initiates students to argue critically nor to look for alternative methods and explanations. However, some educators (e.g., Collins & Pinch, 1994) who are interested in the sociological aspect of science demonstrated the importance of rhetorical devices in arguing for or against the public acceptance of scientific discoveries. Driver et al. (2000) argue further that if our intention is to help students develop the skills of scientific arguments, then science classroom will need to offer opportunities to students to articulate reasons for supporting or refuting a particular claim; to attempt to persuade or convince their peers and to relate alternative views. Such skills could be developed using the second form of informal logic, which is, dialogical argument. Reznitskaya et al (2009) argued that classroom dialogues can serve as a useful mechanism for promoting the development of individual argumentation. By the same token, Costa, Hughes and Pinch (1998) contend that
dialogical argument has a central role to play in teaching science as a social process and in helping students develop the skills of scientific argument.

The implication of the above for science education is that in a multicultural classroom, there are different levels or sites of discourses, which the teacher must be aware of (Ogawa, 2006). Hopefully, such awareness would help them adopt instructional strategies that could minimize the occurrence of symbolic cultural violence in their classrooms. Symbolic violence occurs when a person in the position of authority in a discourse context uses same to marginalize other alternative viewpoints (Bourdieu & Wacquant, 1992).

**Types of dialogues**

Evidence exist that (e.g., Costello & Mitchell, 1995; Walton, 1998) humans employ different kinds of dialogues for achieving different types of goals. Hence, one needs to examine the different types of dialogues to identify which types could: (a) maximize students’ engagement in the social process of science; and (b) help students develop adequate image of science. In addition, one needs to discuss how dialogical and social context influence the characteristic of arguments and clarify how the awareness of these dialogues improve the teaching of argument in science. Kolsto and Ratcliffe (2008) cite several studies on students’ argumentation in dialogues on scientific and other issues. These studies have revealed that students’ dialogues may take different forms. For instance, Mercer (2000) identified three different types of discourses: disputability, cumulative and exploratory talk. On the other hand, Walton (1998) claims the existence of five different types of dialogues. They are persuasion dialogue (e.g., critical discussion), information-seeking dialogue (e.g., interview and expert-consultation), negotiation dialogue (e.g., deal-making), inquiry dialogue (e.g., scientific inquiry and public inquiry) and eristic dialogue (e.g., quarrel).

Kolsto and Ratcliffe (2008) reviewed all the dialogues proposed by Walton and indicated that critical discussion as a type of persuasion dialogue and scientific inquiry as a type of inquiry dialogue are essential in facilitating argumentative discourses in science classrooms. Yet, if our intention is to convey adequate image of science to students, we need to further identify the characteristics of argumentative discourses in science. In a critical discussion as a specific type of persuasion dialogue, the goal is to solve a conflict of opinion by means of rational, or reason based, argumentation. In a scientific inquiry the goal is for the participants collectively to establish or demonstrate a particular scientific claim based on scientific criteria established in a scientific community (Walton, 1998). An important method of scientific inquiry is to collect all relevant evidences, scrutinize the evidence and through collaboration and argumentation identify conclusions that are firmly supported by theory and evidence. Kolsto and Ratcliffe (2008) advanced the case noting that an increased awareness of these two types of dialogues has potential for improving the teaching of argument in science especially in relation to the development of an understanding of the nature of science and the ability to consider socio-scientific issues thoughtfully. The same view is supported by Bell, Blair, Crawford and Lederman (2003) who contend that engaging students in hands-on science activities alone will likely not lead them to appropriate understanding of the nature of science and the scientific enterprise. Rather, students must engage in purposive discussion and reflection on the characteristic of scientific knowledge and the scientific enterprise.

In the light of the above fact, we argue that successful implementation of dialogical argumentation in the form of critical discussion and scientific inquiry will help teachers and students to increase their awareness of the social processes that are involved in the production of scientific knowledge. Such pedagogical practices will also help them to realize that science is a social enterprise and scientific knowledge is socially constructed. This perspective will help students to understand that it is not possible to ground claims for truth in observation alone. Understanding that scientific discoveries are influenced by social, political and
philosophical values and intellectual norms of the culture in the society encourage students to construct scientific knowledge in the social context of their classroom through purposeful discussions and reflections. However, students need to realize that it does not mean that they can claim what they like or that there is no way to evaluate the degree of truth in any claim (Driver, et al., 2000). Valuing the importance of the two types of dialogical arguments, we therefore, strongly recommend that science teachers need to be conscious about the type of social goals they want their students to engage in and design the educational context accordingly. The ultimate goal is to establish the norms of scientific argumentation in classrooms. Finally, we recommend that the science education community needs to advance research in the area of dialogical argumentation and move classroom practices beyond the positivist view of scientific knowledge construction. However, such practices, among others, require development of curriculum material aimed at promoting social norms of argumentation.

Image of science and implications for science curriculum and instruction
Traditionally, science curriculum has focused on what one needs to know to do science. Schwab (1962) call this the “rhetoric of conclusion” approach to science education in which the construction of scientific knowledge is conveyed as empirical, literal and irrevocable truth. “The dominant format in such curriculum materials and pedagogical practices is to reveal, demonstrate, and reinforce via typically short investigations and lessons either (a) what we know as identified in textbooks or by the authority of the teacher or (b) the general process of science without any meaningful connections to relevant contexts or the development of conceptual knowledge” (Duschl, 2007, p.2). However, over the past few decades science educators have taken initiatives to reform science curriculum and the teaching and learning process of science at all school levels (e.g., Penuel & Means, 2004). Costa, Hughes and pinch (1998) cite several studies which show the benefit of including perspectives from science studies (history, philosophy, politics, sociology of science) in science curriculum. The findings from these studies indicate that true educational reform must involve alternative curricula structures. Many researchers in science education have also addressed issues of curriculum and pedagogic practices in order to enhance students’ opportunities for knowing that science is a human enterprise (Driver, 1995; Haren, 2000; Pfundt& Duit,1994). Among others, the American Association for the Advancement of Science (AAAS) and the National Research Council (NRC) advocate that curriculum materials should encompasses not only a fundamental understanding and familiarity with key concepts of science, but also a capacity for knowing that science is a human enterprise (AAAS, 1990,1993, NRC, 1996). Such, curriculum materials might be an important avenue through which students’ understanding is enhanced into ways of knowing associated with the science community. Squire, MaKinster, Barnett, Luehmann and Barab (2003) share the view that classroom culture could be influenced by the curriculum materials used in the classroom. In their attempts to construct a sound argument that draws on scientific evidence and sound reasoning the authors argue that science curriculum materials should focus on ways that would enhance students understanding. By the same token, Wood (1998) explains the need to empower students to practice decision making through the curriculum and to participate in the process of argumentation. Developing students’ argument and counterarguments is likely to broaden students’ understanding of nature of science (NOS), an important objective in science education. One possible way to promote this might be to create NOS-related activities that emphasis argumentation (Walker &Zedler, 2007) in the curriculum material. If our purpose is to promote the social norms of argumentation in science classrooms, and move classroom discourses away from the prevalent positivist view in our classrooms it
seems reasonable then to suggest that such classroom culture would be characterized by active participation of students in the process of inquiry, including the construction and defence of arguments based on data collected while engaging with the curriculum materials. Such participation would require active and successful negotiation of discourses - and various kinds of dialogues-to learn science and achieve the desired social goals, namely, social construction of scientific knowledge.

**Conclusion**

A plethora of studies have shown that science teaching for several decades is dominated by the positivist view characterised by right and wrong answers placing emphasis on factual recall with confirmatory experimentation (Driver et al, 2000; Duschl, 2007). Yet, emphasis only on well-established laws and theories will only reinforce the idea that science is absolute. Consequently, students will remain unfamiliar with how scientists use uncertain and contested knowledge to make decisions. Therefore, we need to move classroom practices away from the positivist view of science as a complete unequivocal enterprise to one which presents scientific knowledge as fragile, dubitable, revisionary and subject to change (Schwab, 1962). A caveat of course is for the teacher to avoid the incidence of cultural symbolic violence when science is used for instance to silence students’ IK or alternative worldviews. Throughout this paper we have argued that the science we teach should reflect NOS the way it is perceived by scientists. We have also argued for the inclusion of dialogical argumentation and discursive practice in science teaching to create conducive learning environment that promotes students’ engagement in discourses. Such practices will help them to: (a) externalize their views and socialize them into new ways of thinking; (b) participate in the process of reflective judgements of their own thoughts and their peers; and ultimately (c) develop an ability to think dialogically and play an active role in resolving political, social, and professional controversies; thereby, contribute towards social transformation of their society.

Our view is that science education has to play a crucial role in developing the skills students will need as future citizens. However, the adoption of any new approach that promotes the use of argument would require a shift in the nature of the discourse in science lessons. In view of this, it seems crucial to organize professional development programmes for improving teachers’ knowledge and skills in teaching argument lesson and in managing student participation in discussion. Moreover, the shift towards the view of social process of science requires inclusion of the role of historical, philosophical and social accounts of science and reorganization of curriculum material. We need to move beyond presenting scientific terminologies, laws and theories and design need-driven, meaningful and contextualized curriculum materials. This calls for science teachers, teacher educators, curriculum designers, stakeholders and other community members to put collaborative efforts to establish the norms of scientific argumentation in science classrooms.

The importance of dialogical argumentation in science teaching illustrates the need to further develop strategies for students who have low self-esteem and/or who encounter difficulties to socialize with their peers. Research shows that overcrowding in many classrooms makes it difficult to implement small group activity (e.g., Brodie, 2004). Thus, further studies are required to successfully implement dialogic argumentation in such classrooms. Studies that examine the effect of the learning environment in the development of the social norms of scientific argumentation are also recommended. The assertion that classroom culture can be influenced by the curriculum material illustrates the need to further examine the nature of science curriculum and develop adequate curriculum materials that would fulfil the social goals of argumentation.
References


The challenge of training Eritrean and South African teachers to implement a culturally relevant science-IK curriculum

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Abstract
Curriculum reform is considered in most countries as a viable means for responding to socio-political changes. To meet the demands of independence African countries have embarked on curriculum reforms compatible to the postulates of their emancipation. A common theme to these curricula is to make education relevant to the daily experiences of the learners. However, the contention of this paper is that well-trained teachers curriculum reforms are unlikely to achieve the goal relevancy. The paper reports the outcomes of some attempts that have been made in Eritrea and South Africa (the focus of this study), to train teachers to implement exemplary science-IK curricula which relate school science to the indigenous knowledge (IK) of the learners. The findings indicate that argumentation instruction was effective in enhancing teachers’ understanding the curricula as well as increased their awareness of the need to implement the curricula in their classrooms.

Background
Curricular reforms are considered as a top priority in most countries of the world. It is regarded as a transformative tool for achieving long-term educational and socio-economic development goals (Lubben, Sadeck, Scholtz, & Braund, 2010; Rose & Barton, 2012). However, the focus of most curricula reforms has been on material development towards an examination-driven educational system rather than the instructional strategies for their implementation at the school level thus creating a yawning gap between curricular idealization and the reality of the classroom. In fact, the neglect of this chasm between theory and practice has been one of the main reasons why teachers have tended to resist curricular innovations (Jansen & Christie, 1999; Ogunniyi, 2004; Rogan, 2003). Significant attempts have been made in the last 50 years to reform the education systems in many countries (Barwell, Bishop, Erduran, & Nyabanyaba, 2007; Rogan, 2003). Like many other countries that have experienced colonial subjection, both Eritrea and South Africa have faced the challenges of political emancipation and consequently set in motion strategies that would authenticate their hard-won independence. It is a well-known fact that political independence without socio-economic independence cannot result in a meaningful development of any country.

The immediate question a reader my want to ask is, “What is the relationship between Eritrea and South Africa?” Our simple response to the question is that the first author comes from Eritrea and the co-author is from South Africa and as such we are interested in finding out areas of common interest. Uppermost in this regard is that: (1) both countries were once colonized and won their independence after a lot of political struggles; (2) both countries in their attempts to authenticate their hard-won independence had embarked on curriculum reforms which they construed as a vehicle for socio-economic transformation; (3) although the immediate needs of Eritrea and South Africa are not exactly the same, they both share the legacy of colonialism which makes them susceptible to neo-colonial exploitation; (4) both countries have also realized the need to train, re-train and upgrade their present calibre of science teachers such that they are able to make school science more relevant to the socio-
cultural environment of all learners regardless of their race, religion, gender or socio-economic status.

**Context of education in Eritrea**

Since its independence in 1991, and to complement the on-going process of nation building, the Eritrean Ministry of Education has undertaken a series of curriculum reforms (MOE, 2010). However, the changes that have been made have been too limited in scope, intensity and coverage (MOE, 2003). Thus, a nation-wide Situational Analysis and Needs Assessment Survey (SANAS) were undertaken in 1996 whereupon formative changes were introduced to the curriculum (MOE, 2010). Findings from the document analysis show that the curriculum was predominantly supply driven, does not satisfy the needs and interests of the trainees and has little relevance to the country’s job market demand (Department of General Education (DGE), 1997; MOE, 2003). The results of the situational analysis and other related research findings led the Government of Eritrea to develop a concept paper for a rapid transformation of the Eritrean education system in 2002. The thrust of SANAS has been to create a qualitative and relevant educational system that could complement national development plans by cultivating highly qualified teachers capable of developing process skills among learners as well as implementing a culturally relevant curriculum. The concept of SANAS paper strongly criticized the former education system in general and the pedagogical strategies employed in classrooms in particular (Government of Eritrea, 2002; MOE, 2010).

In response to the deficiencies reported in the concept paper of SANAS, the Eritrean MOE reviewed the school curricula at all levels and developed new Learner-Centred curriculum in 2005. The new curriculum aims at transforming classroom discourse from a teacher-centred to a learner-centred method, respect the learners’ needs and, thereby, promote learners participation and engagement. The curriculum expects learners to make decisions using critical and creative thinking skills; solve problems, construct their own knowledge and meaning and work with others as members of a team or group (Ministry of Education, 2005). However, the new curriculum gives little to no attention to the importance of integrating IK into school science. MOE envisages the effective implementation of the new learner-centred curriculum in classroom contexts in order to ensure the quality of education offered in the country. However, a report published by the Eritrean Department of General Education (2010) indicates that teachers were employing the traditional approach of teaching and failed to link the lessons with the day-to-day life of students. As a teacher trainer in higher education in Eritrea the first author saw a close similarity between the mandate of the Eritrean curriculum and that of South Africa. She saw the indigenization of the science curriculum being implemented in South Africa as a possible way to make the new curriculum in her country more relevant to the socio-cultural environment of the learners. This forms a good point of departure to consider briefly the South African educational context.

**Context of education in South Africa**

To avoid repetition, the scenario of curriculum reforms in Eritrea sketched above is a vivid reflection of curriculum reforms in South Africa since the demise of apartheid. However, South Africa has gone further by not just discarding the erstwhile apartheid curriculum which is examination-oriented. It has taken a bold step by explicitly stating that Indigenous Knowledge (IK) should be introduced into the science curriculum. The assumption underlying this bold step is that the inclusion of IK into the science is likely to make the latter more relevant to the daily lives of learners. Further, it is construed as one of the measures to rid the old apartheid science curriculum of its euro-centric focus and thus offering learners an opportunity to acquire knowledge critical to their intellectual emancipation and sense of actualization (Ogunniyi, 2004; Kwofie & Ogunniyi, 2011). The same general aims stress the need to make “inclusivity” the central core of the organization, planning and teaching at each
school. However, this can only happen if teachers have a sound understanding of “how to recognize and address barriers to learning, and how to plan for diversity” (NCS, 2011, p.5). South Africa like Eritrea is construes curriculum reforms as a transformative agent for long-term educational, social and economic goals. However, as indicated earlier the focus of curriculum reform in South Africa is still on the content at the expense of the instructional strategies for their implementation at the school level. In fact, the neglect of the latter has been one of the main reasons why teachers have tended to resist the new curriculum since its inception in 1997 (Jansen & Christie, 1999; Ogunniyi, 2004; Rogan, 2003).

Since its inception in 1997, the new outcomes-based curriculum in South Africa and elsewhere has received a lot of public criticisms. Critics have called for its total abrogation and to replace it with what they call “back-to-basics curriculum” (Jansen & Christie, 1999; Ogunniyi, 2004, 2007a & b, 2011). Jansen, at the forefront of the antagonists of the curriculum posited 10 reasons why the curriculum would fail; the most pronounced of these being the poor preparation of teachers, the incoherence of the curriculum and related assessment documents, the vagueness of the standards for the phases, the lack of textbooks, the top-down implementation approach used, and the watering down of the subjects (Jansen & Christie, 1999). Despite the spirited attempts that have been made by the Department of Education to improve the quality of the curriculum, the general consensus among science educators and the public at large is that the new curriculum is inferior to the apartheid curriculum (Ogunniyi 1998, 2004; Rogan, 2003).

Further, in response to the public’s outcry, the new curriculum has been revised thrice i.e. in 2000, 2002 and 2009. In 2011 the Curriculum and Assessment Policy Statement (CAPS) was formulated to specify what should be taught and learned. This has been a remarkable departure from the original phase-based to a grade-based curriculum i.e. junior (grades 1-3), intermediate (grades 4-6), senior phase (grades 7-9) and Further Education and Training (FET) (grades 10-12). In her defence of the new curriculum the current Minister of Basic Education and the fourth Minister in that portfolio, has made the following remark:

Our national curriculum is the culmination of our efforts over a period of seventeen years to transform the curriculum bequeathed to us by apartheid. From the start of democracy we have built our curriculum on the values that inspired our Constitution (Act 108 of 1996)...In 1997 we introduced outcomes-based education to overcome the curricular divisions of the past, but the experience of implementation prompted a review in 2000. This led to the first curricular revision: the Revised National Curriculum Statement Grades R-9 and the National Curriculum Statement Grades 10-12 in 2002. Ongoing implementation challenges resulted in another review in 2009. From 2012 the two National Curriculum Statements, for Grades R-9 and Grades 10-12 respectively, are combined in a single document and will simply be known as the National Curriculum Statement R-12. The National Curriculum Statement for Grades R-12 builds on the previous curriculum but also updates it and aims to provide clearer specification of what is to be taught and learnt on a term-by-term basis (Motshekga, 2011: forward page).

Since the release of the CAPS there has been a new wave of criticisms ranging from its abandonment of its original goal of social relevance (Ogunniyi, 2011; Onwu & Kyle, 2011). Earlier studies have shown that most South African teachers were initially opposed to the curriculum both in terms of its outcomes-based emphasis as well as the nature of its inclusiveness of knowledges not strictly scientific. Like any new curricular innovation, the new curriculum probably challenged the teachers’ belief that science and indigenous knowledge are incompatible or that the latter could be a valid way to interpret human experiences with nature (e.g. Ogunniyi, 2004, 2007a & b; Ogunniyi & Hewson, 2008a; Jansen & Christie, 1999; Rogan, 2003).
The challenge of inclusivity
Whatever stance one takes there is general consensus among scholars that for a curriculum to be relevant to the daily lives of learners it must find a means to link what they learn at school to what they encounter at home or outside the school. In other words, a relevant curriculum should resonate with the intellectual interests, and indigenous knowledge or values of learners. Our contention therefore is that the new curricula in both countries have attempted to embed as much as possible learners’ school experiences within their indigenous or daily lives. This is because knowledge, beliefs, interests and values are the products of a given culture. No one lives in a cultural vacuum. As Rose and Barton (2012:542) succinctly put it, “Concerns and values do not exist in abstract, but rather grow out of the context that gives rise to them.”

A cursory review of the literature would show that indigenous knowledge (IK) has been defined in a variety of ways. Some have called it endogenous knowledge while others have called it traditional or local knowledge. Although scholars have defined IK in a variety of ways, all agreed that it has something to do with the local or endemic knowledge practices unique to a given culture or groups of people that are critical for their survival and sustainability (Ogunniyi, 2004; DOE, 2011; Government of Eritrea, 2002; MOE, 2003, 2010; Mosimege & Onwu, 2004; UNESCO, 2010). To Ogunniyi (2007a) IK is not just about artefacts but also entails the epistemologies, ontologies and metaphysical systems underpinning these artefacts and the way they are used to create a sense of wholeness, relatedness, or complementary amidst a collocation of human dilemmas” (p. 965).

In view of the prominence of IK, various scholars (e.g., Aikenhead, & Huntley, 2002; Emeagwali, 2003; Ogunniyi, 2007a &b, 2011; Ogunniyi and Hewson 2008) have argued for the importance of connecting school science education with the learners’ cultural backgrounds. There seem to be a need for a science curriculum that would require a science educational perspective that views science as a process of crossing the border between the learners’ worldview and the scientific worldview (Ogunniyi 2005). Parallel to this, several scholars (e.g. Aikenhead, & Huntley, 2002; Cajete, 1994; Dziva, Mpofu & Kusure, 2011; McKinley, 2005; Mosimege & Onwu, 2004) have contended that if a learner-centered approach is to be taken seriously it should include the traditional cultural knowledge which they bring into the science classroom. The attainment of such contention depends on the ability of teachers to relate school science with students’ cultural background and in particular their IKS. Yet, most science teachers are unaware about how to achieve this goal. This issue forms the central concern of the paper.

Many studies have attempted to link school science with learners’ daily experiences outside the school environment. In this regard, Jimenez-Aleixandre and Erduran (2008) have contended that the lack of the transformation of policy recommendations to educational practice is a major challenge to implementing new instructional practices in the actual classrooms. To minimize the gap Ogunniyi and associates conducted a research project based on argumentation framework to equip science teachers with knowledge and skills to integrate science and IK in their classrooms (e.g. Hewson & Ogunniyi, 2011; Langenhoven & Ogunniyi, 2009; Ogunniyi, 2004, 2005, 2007a, 2007b, 2011; Ogunniyi & Ogawa, 2008).

Argumentation as instructional tool
Science as an argumentative enterprise has been widely advocated as a framework for science education (Berland & Reiser, 2009; Bricker & Bell, 2009; Driver, Newton, & Osborne 2000, Dushl, 2007; Jimenez-Aleixandre, & Erduran, 2008). A significant body of argumentation literature in science education has been based on Toulmin’s work (e.g., Erduran, Simon, & Osborne 2004; Jimenez-Aleixandre & Erduran, 2008). TAP illustrates the structure of an
argument in terms of an interconnected set of claim; data that support that claim; warrants that provide a link between the data and the claim; backing that strengthen the warrants and rebuttals which point to the circumstances under which the claim would not hold true (Erduran et al., 2004). However, scholars (e.g., Erduran, 2008; Kelly & Takao, 2002; Simon, Osborne, & Erduran, 2003) assert that despite its use as a framework for defining argument, the application of TAP to the analysis of classroom-based verbal data has yield difficulties. In response to these difficulties, scholars have modified TAP analytical framework to obtain more robust units of analysis of classroom interactions (e.g., Clark & Sampson, 2008; Erduran, Simon, & Osborne 2004; Oggunniyi, 2004, 2007a).

Ogunniyi (2004) proposed the Contiguity Argumentation Theory (CAT) as an alternative to TAP because according to him the latter does not explain the non-logical aspect of human experience (Ogunniyi, & Hewson, 2008). CAT posits that when people with an indigenous worldview are confronted with scientific worldview on a subject, they try and juxtapose the two systems of thought to some meaningful level co-existence or seek for equilibrium between these competing worldviews. Msimanga & Lellott (2010) construe argumentation as a teaching strategy and a tool for knowledge construction. Argumentation-based instructional model as a teaching strategy has the potential to stimulate learner participation and engagement in structured discussion in science classrooms. In the same vein, Siegel (1992) argues that argumentation plays a central role in the building of exploration, models and theories as scientists use argumentation to relate the evidence they select to the claims they reach through the use of warrants and backing.

Duschl and Osborne (2002) have contended that argumentation could also help learners develop complex-reasoning and critical-thinking skills, understand the nature and development of scientific knowledge, and improve their communication skills. Erduran, Osborne and Simon (2004a) add that interactive classroom argument and dialogue encourage teachers and students to externalize their view points and present valid reasoning for different stances. It is with this understanding, that science educators such as Mason (1994) argue that argumentation should be appropriated by children and explicitly taught through suitable instruction, task structured and modelling. Newton, Driver and Osborne (1999) provide several convincing reasons for the explicit teaching of argumentation in science classrooms. Thus, teachers need to adopt more dialogic approaches (Mortimer & Scott, 2003; Alexander, 2005) that involve students in discussion, and to consider how they themselves interact with students to foster argumentation skills.

School-based research in integrating science and indigenous knowledge
In view of the positive results emanating from argumentation studies in many parts of the world (e.g. Erduran, Osborne & Simon, 2004; Duschl & Osborne, 2002; Kelly & Takao, 2002; Simon, Osborne & Erduran, 2006) Oggunniyi and associates (Oggunniyi, 2004, 2006, 2007a & b; Oggunniyi & Hewson, 2008; Oggunniyi & Ogawa, 2008) carried out a series of studies using an argumentation framework. Our review of these studies shows that argumentation instruction could bring about the following outcomes:
Serves as an exemplary instructional approach for implementing an arguably controversial curriculum.
Is more amenable to classroom discourse than traditional instruction familiar to most teachers.
Provides the necessary intellectual space for the teachers to express their views about the new curriculum
Reveal teachers’ beliefs which could impact their professional practice.
Has potential for ameliorating possible instances of symbolic violence in a classroom discourse e.g. in cases where power relations are abused through the marginalization of other competing or alternative viewpoints expressed by others (e.g. Bourdieu & Wacquant, 1992; Erduran et al, 2004; Kuhn, 1993; Skoumios, et al, 2009).

**Conclusion**

In the light of the forgoing, it seems that despite the misgivings that practising and teachers might have about using argumentation instruction to implement a learner-centred curriculum in the case of Eritrea or indigenized curriculum in the case of South Africa. Training teachers on how to use argumentation to generate classroom discourses and for giving voice to learners seems to us the way to go. Findings in both Eritrea and South Africa have supported the position that the most effective way to get teachers to be involved in the implementation of the new curriculum is to engage workshops and seminars where they can interact and make their own contribution to curriculum development and implementation. However, the achievement of this goal implies involving them in a long-term mentoring process (Ogunniyi, 2005, 2006).

It is also apposite to point out that science teacher educators should be conversant with the conceptions and importance of a learner central curriculum, the importance of their sociocultural beliefs and values as well as the potential of argumentation instruction for fostering learners’ participation in classroom discourses. In the same vein, the organization of in-service refresher courses in form of seminars and/or workshops should be among the top priorities of policy makers, curricular designers and associated bodies in both Eritrea and South Africa. Moreover, policy makers in both countries need to set national policies that allow a wider use of the applications of new pedagogical strategies such as argumentation instruction. As indicated by Cobern & Loving (2001) curriculum developers need to consider IK as a tool for learning about culture-laden nature-knowledge systems and that learners should be helped to understand that all knowledge systems are culture laden, including Western Modern Science (WMS).

**References**


Exploring the nature of knowledge building among teachers using the argumentation instructional strategy– reflections from a community of practice

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Abstract

This article reports on a study conducted to explore the nature of knowledge building in a group of science education practitioners who have been introduced to an argumentation instructional strategy. Data on the reflections obtained from these practitioners were collected through a survey and were analysed using both quantitative and qualitative methods. The findings from the study have shown that argumentation is a critical tool, which, if applied to science education, will enhance rationality in the scientific discourse among science learners, thereby enabling them to conceptualise abstract concepts. From the findings, it has become apparent that science has a social construct, meaning that science can no longer be seen as separate from the socio-cultural setting of a community. Although the findings of the study show that argumentation presents significant opportunities for the social construction of knowledge in science education, a number of science teachers are not using it, citing a lack of pedagogical knowledge. The implications of these findings are discussed in detail in the study.

Key words: Nature of knowledge, argumentation instructional model, reflection, community of practice

INTRODUCTION

The paper is based on the reflections on the nature of knowledge building obtained from twenty participants who attended training workshops and seminars about the integration of science and Indigenous Knowledge (IK) using argumentation. The participants include, among others: teachers, teacher education facilitators, science education students, researchers in science education and individuals whose interests are in science education. These participants are part of the Science and Indigenous Knowledge Systems Project (SIKSP) group for a period ranging from six months to four years. Essentially, the SIKSP group is a Community of Practice (COP). The aims of the SIKSP project were to introduce participants to argumentation as an instructional strategy, to conduct research on the merits of using argumentation in science education, and to investigate how to promote the integration of IK and science in science education. Throughout this paper, we use the term science to mean “modern science” which in our opinion fails to take into account the socio-cultural backgrounds of the learners. In sum, the study reports on the nature of knowledge building among the participants who were exposed to the Argumentation Instructional Strategy (AIS). In their responses, they described their growth paths after being exposed to AIS.

We begin by explaining what argumentation entails, before discussing the rationale for using argumentation in science classrooms. Recent lines of research (Driver et al, 1999; Krummheur, 1995) have shown that at the core of effective classroom science discourse is
the use of argumentation. An argument is either individual or monologue – i.e. a single line of thought, or it is dialogical and social – particularly where a number of contrasting reasoning lines are developed (Billig, 1987; Driver et al, 2002). According to Billig (1987), an argument is discourse that presents an individual’s view point. Kuhn (1993) further explains that both individual and social arguments lead to higher order thinking or internal argumentation. Kuhn adds that, through participation in social dialogue, internal thinking strategies that are embedded in argumentation can be exposed or externalised. In this paper, we hold the view that the difference between “a discussion” and “an argument” is that an argument is a sub-set of a discussion, whose aim it is to resolve a specific controversy. However, we have used the terms “discussion” and “argument” loosely to mean the same thing.

Based on the above explanations, argumentation can be defined as the construction of knowledge through discourse. It can also mean persuasion. Eemeren et al (2004) and Meyers (1990) define scientific argumentation as constructing knowledge by using data or evidence, either empirical or theoretical, to support a claim. However, there are few opportunities for the social construction of knowledge in science education, hence the urgent call for the promotion and adoption of AIS in science education (Duschl & Osborne, 2002; Driver et al, 1998, 2000; Erduran, 2006; Kuhn, 1992’ Ogunniyi, 2009). The next section looks more closely at argumentation theory. We have used the terms argumentation theory and argumentation synonymously throughout this paper.

What is argumentation theory?

The South African Government is in the process of implementing a new curriculum whose ethos includes acknowledging the rich cultural heritage of its multicultural societies and encouraging greater learner centeredness in teaching and learning science (DST, 2004; NCS, 2002). The inclusion of IK in the science curriculum calls for teaching methods, where learners become active participants and educators become facilitators. In such a context, argumentation is an effective forum for encouraging the active participation of learners. Toulmin, Rieke and Janik (1984:14) defined argumentation as “the whole activity of making claims, challenging them, backing them up by producing reasons, criticising those reasons, rebutting those criticisms, and so on”. In this paper, we refer Toulmin’s (1958) Argumentation Pattern (TAP), which has featured prominently in science education research in recent years. Essentially, the TAP consists of six components in reasoning, from obtaining and presenting data to claiming knowledge. These components consist of: data (facts or evidence that support a claim or an assertion), a claim (an assertion, a declarative statement or a conclusion whose merits are to be validated), warrants (these are the reasons that are proposed to justify the relationship or connection between the data and the claim), backings (basic assumptions, which are commonly agreed to provide justification for particular warrants), qualifiers (specific conditions under which the claim can be either accepted or limited), and rebuttals (these are valid counter-claims) (Bulgren & Ellis, 2012; Driver et al, 1998, 1999; Ogunniyi, 2007; Duschl, 2008). Before we delve into the implications of argumentation in science education, we need to acknowledge that, whilst the TAP provides a useful structural account of arguments, it needs to be supported by socio-cultural contexts for meaningful discussions to take place. We believe that there is a convergence between advances in educational theories that have been inspired by socio-cultural models of learning, and advances in the theory of argumentation (proposed by Toulmin’s [1958] argumentation theory). Therefore, in order to enhance the role of argumentation in science education, we propose that teachers adopt a teaching approach that promotes the use of argumentation.
within the framework of situated learning (Driver et al, 2000; Munford & Zembal-Saul, 2002).

**Implications of argumentation in science education**

There have been growing concerns about the hegemonic power of western science and its lack of social context in how it tends to portray nature (Aikenhead, 2002; Battiste, 2005; Ogawa, 1995). Worldwide there has been an increase for science education to be more pluralistic in approach, by calling for the inclusion of other ways of interpreting nature as part of the science curriculum. South Africa is one of the countries in the developing world whose curricula are being restructured to be more inclusive of its peoples’ different cultures as a way of making learning more meaningful and relevant to learners (Onwu & Mogege, 2004; Ogunniyi, 2007). Meaningful science learning in this regard is captured by Aikenhead’s (1997) assertion that classroom science would be more relevant to indigenous learners if it were guided by a curriculum framework that acknowledges IK. The integration of IK with science in learning and teaching calls for a change in teaching strategies, and specifically for the adoption of argumentation in science teaching (Ogunniyi & Kwofie, 2011; Siegel, 1995; Ogunniyi & Ogawa, 2008). This has led to studies that focus on the analysis of argumentation discourse in science learning and teaching contexts. The use of argumentation has important implications on teaching and learning in science education. The reasons are many and varied. Firstly, the use of argumentation in the classrooms provides learners with the opportunity to experience scientific practices foregrounded in and applied to contexts that are familiar to the students. In other words, students would learn about science broadly – including its intrinsic values instead of merely knowing the science concepts (Brown et al, 1989; Driver et al, 2000). Secondly, through argumentation, learners become active participants in the construction and production of scientific knowledge as opposed to mere consumers of knowledge (Boulter & Gilbert, 1995; Driver et al, 2000; Erduran et al, 2004; Jimenez-Aleixandre et al, 2000; Knorr-Cetina, 1999). Thirdly, argumentation recognises the existence of science and IK as different ways of thinking, which facilitates science learning by acknowledging the role of language, culture and social interaction in the process of knowledge construction (Vygotsky, 1978; Wertsch, 1991). Fourthly, using argumentation in the classroom makes the learners’ understanding and thinking processes visible to the teachers, which thus represents a tool for both assessment and self-assessment for learners and teachers respectively. Finally, argumentation allows the learners to participate in public discourses outside the science classrooms; this means that the skills they learn by presenting a cogent, logical, rational argument in the classroom can be applied outside the school environment – thus contributing to the development of good citizenship (Jimenez-Aleixandre & Erduran, 2005). The skills gained by learning argumentation in a science classroom are critical for the development of citizenship. Young people will need to confront complex public issues such as air pollution, genetic engineering of foods, healthy life styles and the use of organic fertilisers. Not only are these issues complex, but they also require complex data analysis. In this paper, we argue that for the learners to understand these public discourses and to make an informed judgement on a particular public issue, they will need to understand the claims and counter-claims that are being made and to consider the evidence provided in the discourse. This involves putting argumentation into practice. According to Driver et al (1998;301), argumentation is also important in public discourse in the sense that it provides the public “with a more authentic image of what is involved in scientific inquiry”. In conclusion, we thus posit that argumentation lies at the heart of knowledge construction in science and in society in general.
COP – SIKSP group

We have alluded to the fact that this study is based on the reflections of teachers in a COP. “Communities of practice are a group of people who share a concern or passion for something they do and learn how to do it better as they interact regularly” (Wenger, 2004:1). The SIKSP group is one such group; it is made up of science teachers, teacher education facilitators, science education students, researchers in science education and individuals whose interests lie in science education. Their common interest centres on the integration of science and IK. In addition, the SIKSP group’s aims are to: produce teaching resource materials for science teachers, create awareness of how IK and science can be integrated, to build IK data achieves that could be used by science teachers as resources, and use postgraduate research as a vehicle to deepen their understanding of argumentation. In view of the differences between Science and IK, they also use argumentation as a way of evaluating scientific claims, challenging, backing and rebutting them (Rieke and Janik, 1984; Toulmin, 1958).

Three components make up the COP. First is the domain, which refers to the shared goals of deepening understanding of the integration of IK and science through argumentation. Second, community members engage in joint workshops, seminars, lectures and research, including reflections about the integration of science and IK. The last component is the practice: As practitioners, group members and teachers develop a shared repertoire of resources, such as: lesson plans, notes, science kits, theories of learning, research outputs. They furthermore reflect on their practices.

Reflective practices

The SIKSP group as a COP values reflective practices. Loughran (2002:33) defines a reflective practice as: “... a meaningful way of approaching learning about teaching so that a better understanding of teaching, and teaching about teaching, might develop”. Reflective practices are important in two ways: firstly, they offer a variety of approaches to examining practice and researching some of the assumptions that influence our daily work as teachers. Secondly, they provide an opportunity to understand the professional experiences of teachers (Brookfield, 1995). Although there are many types of reflections, for the purposes of this study, we will only focus on three. The first is the personal reflection, which is concerned with one’s personal growth, including one’s thoughts, actions and relationships with students. It connects the teacher’s identity to the teaching profession, seeking to understand whether the individual’s career goal suits her/his personality. Such personal reflections lead to introspection (Colbourne and Sque, 2004), which enhances self-awareness; practitioners also look at how their personalities affect their learners. Personal reflection goes beyond pedagogy to include issues such as the learners’ cultural, ethnic or life struggles, including their goals. The second type of reflections is contextual reflections, which look at concepts, theories and methods in science education. It includes interactions with other things, for example, teaching concerns about students and colleagues, curriculum, instructional strategies, rules, classroom management, and the communities from which learners come. With all these pressures facing the teacher, he/she must choose the most suitable and effective path to follow in the classroom. The third type of reflections concerns one’s personal teaching performance. So-called reflection-in-action takes place whilst the lesson is in progress, whilst reflection-on-action happens after a lesson, and it is the most commonly practised form of reflection by teachers (Carlo, Hinkhouse & Isbell, 2010; Larivee, 2000; Valli, 1997).

FOCUS OF THE STUDY
The study is based on the reflections of twenty participants belonging to the SIKSP on the issue of using argumentation in the science classroom, and the integration of IK with science education. The participants are mostly postgraduate researchers in science education or individuals whose interests lie in science education. From their reflections, three domains of knowledge building were identified, namely, self-awareness, intellectual growth, and the nature of IK and the nature of science. These three domains will be discussed under the findings section.

**Research question**

The research question underpinning this study is: What is the nature of knowledge building among teachers in the SIKSP group, using argumentation as an instructional strategy?

**METHOD**

This research was carried out using both a qualitative and a quantitative approach. Twenty participants from the SIKSP group responded to a survey, which comprised the following four open-ended questions:

1. How have your experiences in the SIKSP or related activities (modules, seminars and workshops) informed the way you frame (i.e. bring coherence to, or make sense of) the pieces of information or experiences you have acquired, particularly in terms of the way you construed the controversial issue of integrating science and IK at the time you started participating in the activities, during the period of your involvement, and now?
2. Were you once opposed to the new curriculum? If yes, why? If not, why not? Have you changed your view over time and, if so, how?
3. How have you leveraged, reorganized or integrated your frames with your personal experiences with respect to science, IK or the integration of IK and science in the classroom?
4. How have the frames constructed from your experiences in the lectures, seminars and workshops prepared you to use argumentation instruction in teaching a controversial subject, such as the integration of science and IK?

Responses from these questions were intended to provide an overview of the nature of knowledge building among teachers in the SIKSP group who are either using argumentation as an instructional strategy in science classrooms or carrying out research work in science education. For the purposes of analysing the data, discourse analysis was used. Data from the responses of the teachers were coded and grouped into categories. From the categories, three domains emerged: self-awareness, intellectual growth, and awareness of the nature of IK and the nature of science emerged. Participation in the study by teachers was voluntary. For the purposes of qualitative analysis and anonymity, each teacher was given a pseudo-name identified by two capital letters, for example “AB”.
FINDINGS

As mentioned above, three domains emerged from the analysis of the teachers’ reflections on the nature of knowledge building, namely: self-awareness, intellectual growth, and awareness of the nature of science and the nature of IK. Self-awareness, the first domain, can be construed as an understanding of one’s own knowledge, attitudes, beliefs and opinions in respect to argumentation as an instructional model and the integration of IK in the science curriculum. Self-awareness allows an individual to change thought processes and interpretations. Exposure to a practice such as the AIS develops self-awareness towards the practice, thus giving individuals clearer perceptions about themselves, such as their personality, including weaknesses, strengths, thoughts and emotions about the practice. It furthermore leads to self-efficacy (Bandura & Cervone, 1983).

The second domain, viz. relating to awareness of the nature of science and the nature of IK, covers the generally accepted notion by scientists of differences between science and IK. Science is regarded as universal, whereas IK is restricted only to a particular geographical location and to a unique socio-cultural environment: they thus represent two different world views. Science focuses on knowledge, while to a certain extent giving less attention to the notion of science knowledge as a social construct, whereas IK views the world in a holistic way. In this paper, we posit that science and IK can co-exist in a multi-cultural approach in teaching classroom science (Aikenhead and Jegede, 1999). It is worth noting that in this contemporary world, knowledge is constantly changing to accommodate new ideas (Agrawal, 1995, Morphy, 1991, Snivel & Corsiglia, 2001).

Lastly, the third domain of intellectual growth is not merely about knowing facts and knowledge accumulation about a phenomenon, it is also about making connections with world views and locating one’s self within the context of other people’s beliefs. In addition, according to the teachers’ reflections, intellectual growth is enhanced by doing postgraduate research, participating in the production of science and IK learning materials, and using argumentation to integrate science and IK in schools.

In the following section, we discuss the reflections from teachers within the three domains.

The first domain: Self-awareness

In this self-awareness domain, the analysis of the teachers’ reflections on the integration of IK and science in the new curriculum has raised three issues. Firstly, eleven (55%) of the participating teachers said that they were in favour of the section of the new science curriculum that sought to integrate IK into science, giving five reasons. Seven (35%) of the participants argued that such integration would add a socio-cultural perspective to science education; in other words, it would increase awareness of culture and identity. In addition, it can also be argued that modern challenges, for example, environmental issues, are better solved from social and cultural points of view in addition to scientific approaches. In support of this view, one teacher (OA) claims:

“I was never opposed to the new curriculum because I understood its intent and purpose as being an attempt to bridge the distance between science and the lived experience of ordinary people in their communities and their cultural ways of learning.”
Table 1: Perceptions of teachers about integrating science and IK

<table>
<thead>
<tr>
<th>Category</th>
<th>Reasons</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>In favour of integrating IK &amp; Science in new curriculum (11)</td>
<td>To add a socio-cultural context to the learning of science (7)</td>
<td>7</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>IK informs modern science (4)</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>Opposed to integrating IK &amp; Science in the new curriculum (7)</td>
<td>Lack of support for teachers in terms of professional development and availability of resources (6)</td>
<td>6</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Lack of conceptual understanding of IK (1)</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Undecided (2)</td>
<td>Lack of support for teachers in terms of professional development and availability of resources (1)</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Failed to see the immediate benefits of the integration, such as: improving pass rates in science, change in the South African science community (1)</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

Four (20%) of the participants were of the view that “IK informs modern science”. Key to this assertion is the realisation that, even though IK and science are based on different world views, they complement each other.

Secondly, among the teachers who took part in the survey, seven (35%) indicated that they were opposed to the integration of science and IK in science education, giving two main reasons. Six of the seven teachers in this category said they were opposed to the integration because of a lack of support for teachers in terms of professional development and because of a lack of teaching resources. One teacher (DM) declared:

“I also realized the teachers were not ready for this type of curriculum, especially the section where the integration of science and IKS is required. I still feel teachers need to be professionally developed on how to integrate science and IK.”

DM is referring to the lack of professional development that is exacerbated by a lack of relevant qualifications among teachers; according to research, these are some of the current challenges faced by South African teachers (Makgato & Mji, 2006; Reddy et al, 2006).

Lastly, two participants acknowledged that they were undecided about the integration of IK and science, one of them saying that he/she did not see how this integration would improve the pass rates in sciences in high schools or how it would help to enhance the scientific literacy of the communities. This argument was echoed by one of the teachers (SS) who stated: “My other confusion was how this may help to solve the current high failure rate in science that South Africa is experiencing.” The participant (SS’s comments brings to our attention one of the broader challenges faced by the South African science education – the issue of high failure rates in science. There could be several reasons which results in the poor performance in science subjects. In the light of the discourse of this paper, we argue that bringing in IK in science education could be a way of anchoring the teaching of science in the
socio-cultural contexts of the learners. This would give relevance and meaning to science education, in addition to motivating the students.

**The second domain: Awareness of the nature of science and the nature of IK**

In Table 1 above, the reason cited by seven (35%) of the teachers in favour of the integration of science and IK was “to add a socio-cultural context to the learning of science”. This is testimony to show that IK is a social construct, whereas modern science is made up of components that are universally accepted. Examples of such components are concepts such as weight and length. In contrast, IK communities had different ways of measuring weight and length. Not all IK is compatible with science, however. Some researchers have shown that concepts such as the atomic model, which are not necessarily dependant on the socio-cultural context of knowledge, may not be assimilated through the integration of IK and science (El-Khalick & El-Mona, 2010). This is succinctly articulated by one of the participants (SD), who noted: “I feel it is important to isolate IK practices which have a practical or empirical application and then compare that to the modern science application.” We find (SD)’s argument relevant in the sense that it supports the notion that IK to some extent informs modern sciences – in a more validated manner.

**The third domain: Intellectual growth**

Teachers working on the integration of the two world views relating to IK and science have been involved in various intellectual activities, such as: postgraduate research on IK and science, development of IK and science teaching resources, and at personal level, identifying how the intrinsic values of IK and science can jointly benefit communities. Seventeen (85%) of the participants surveyed are in fact doing postgraduate research on IK and science – focussing on the use of argumentation as an instructional strategy in the teaching of high school science. Through research and postgraduate studies, teachers deepen their understanding of the nature of IK and the nature of science. One teacher (FG) claimed: “When exposed to IKS in my honours and Master degree training, the relevance and importance became clearer to me.”

A deeper understanding of the two world views has important implications in the teaching of school science – put more simply, teachers who are empowered or knowledgeable about IK are most likely to integrate it in their teaching. Intellectual growth was also facilitated by activities such as designing and producing an IK and science resource book, which was intended to alleviate the lack of such teaching materials. Six (30%) of the teachers said that they had acquired the intellectual capacity to apply the knowledge gained in SIKSP workshops, seminars, research and lectures to other socio-cultural contexts of their lives, such as the use of traditional herbs to treat minor ailments, for example, neutralising the pain experienced by an individual after being stung by a bee. They cited numerous examples where they used IK; one teacher (BM) explained, for instance:

“I have integrated this knowledge in various ways at grade nine level (natural sciences). For example, I have introduced indigenous sanitary pads for girls during the menstrual cycle (Reproduction). I have also engaged them in various debates concerning use of various indigenous medications for various ailments.”

The classification of knowledge between the three domains of self-awareness, awareness of the nature of IK and the nature of science, and intellectual growth is quite weak (Sadovnick,
This means that these three domains are not mutually exclusive, to the extent that some of the descriptors discussed, for example under intellectual growth, could well be pertinent to another domain and vice versa.

Conclusion
In our analysis of the reflections of teachers on the role of AIS in the integration of science and IK in science curriculum, we are cognisant of the fact that AIS is a new field that has only emerged in the last decade within the broader context of science education. Through analysing the reflections of teachers in the SIKSP group, several important points relating to the use of argumentation in science education surfaced. Firstly, there is significant support for the use of AIS in the teaching of science in school from the SIKSP group. On the one hand, this was expected, given that the SIKSP group is a COP whose prime goal is to deepen their understanding of AIS through research and science classroom practice. On the other hand, there is also growing acknowledgement of the key roles that AIS plays in science education. However, recent research (Kuhn, 1993 & 1992) has shown that, for various reasons, the adoption of AIS in science education at classroom level has made only very insignificant progress. One of the main reasons for this appears to be the lack of skills on the part of teachers on how to use AIS, coupled with a lack of teaching resources. If AIS is to be used in science classrooms, then greater emphasis needs to be placed on teacher training and professional development programmes that enhance their pedagogical knowledge of this teaching method. The SIKSP group as a COP is an excellent example where shared experiences on AIS have resulted in personal and intellectual growth. The findings have also shown that science has a social construct, meaning that science can no longer be seen separate from the socio-cultural setting of a community. This study has found that the missing link in ensuring successful learning in developing countries is the integration of IK and social and cultural contexts into science education, supported by the greater use of AIS. In fact, successful science learning environments, we argue, should be fostered when science features significantly in popular culture or IK (Dzama & Osborne, 1999). Hence, in conclusion, we posit that, if the future of teaching science lies in its ability to empower students with the skills to think scientifically about public issues that require informed citizens to make judgements, then AIS should be central to science education.

References


The role of Indigenous Knowledge Systems in enhancing grade 9 learners’ understanding of a Natural Science Education Curriculum: An survey in a Geography classroom in Cape Town, South Africa.

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Abstract
This paper looks at the role of Indigenous Knowledge Systems (IKS) in enhancing learners’ understanding of the concepts in a Natural Science and Social Sciences Curriculum, with specific reference to a geography classroom. During the survey, pre-post-test and observation stages of the author’s main research study, with a quasi-experimental case study-type of design, what became apparent was that IKS are preserved in the memories of elders of ‘indigenous’ communities, and that this knowledge is gradually disappearing due to memory lapses and the deaths of the custodians of this knowledge. Cultural knowledge that could enhance learners’ understanding of difficult concepts in a science or geography classroom is slowly fading and disappearing from the cultural heritage of our communities. The DAIM-model (Dialogical Argumentation Instructional Model), and a quasi-experimental research design model, incorporating both quantitative and qualitative research methods (‘mixed methods’), was employed to collect data in a public secondary school in Cape Town in the Western Cape. In the main research study, a survey questionnaire on the attitudes and perceptions of grade 9 learners towards high school, as well as their conceptions of weather (CoW), was administered before the main study to give the researcher some background information for use in piloting an instrument to be used in the main study. The study then employed a dialogical instructional model (DAIM) with an experimental group (E-group) of learners who had been exposed to the intervention stage, and noted and recorded differences from between the responses of this group and the control group (C-group) which had had no intervention. Learners from the two groups were than exposed to a MLT (Meteorological Literacy Test) pre-post evaluation test before and after the DAIM intervention. The results from the two groups were then compared and analysed according to the two theoretical frameworks that underpinned the study: Toulmin’s Argumentation Pattern - TAP (Toulmin, 1958) and Contiguity Argumentation Theory - CAT (Ogunniyi, 1997). Further analyses were conducted of learners’ beliefs and indigenous knowledge according to their conceptual understanding of the weather related concepts used in the NCS (National Curriculum Statement), in current use at the time of the study, of the Department of Education. Some interesting findings emerged from the study, and, based on these findings, certain recommendations were suggested on how to implement a DAIM-model in the classroom using, or incorporating, IKS content. These recommendations are in the form of suggestions to clear the way towards developing a science–IK curriculum for the Natural Sciences and Social Sciences in all South African schools. For the purposes of this paper, we will focus on the first part of the quasi-experimental design research method, which is the learner survey and pre-test results, the purpose of the paper being to describe the process used in determining learners’ perceptions of IKS and weather related concepts, and to offer suggestions in terms of integrating IKS in a science curriculum.
**Introduction**

Although most people are interested and concerned about the weather, they do not always understand the concepts and processes involved in weather and climate change. This is particularly the case at school level, where teachers rush to complete the syllabus and to keep up with the requirements of the National Curriculum Statement (NCS) and with the new Curriculum Assessment Policy Statement (CAPS) and learners do not always understand when science concepts are hastily explained or delivered. In this context, it would be useful to be able to answer certain questions arising from the exposure of grade 9 learners to a dialogical argumentation instructional model (DAIM) dealing with meteorological science/IK concepts: (1) What kinds of meteorological concepts do grade 9 learners have? (2) Are grade 9 learners’ meteorological conceptions related to their age, gender or socio-economic backgrounds? (3) What are grade 9 learners’ conceptual understandings of weather?

Geography as a subject includes environmental education and environmental literacy. An important goal of environmental education is to assist learners in developing an understanding of environmental and climate changes as well as sensitive and responsible attitudes towards their environment. It would be of value to examine what role indigenous knowledge can play in achieving this goal. Indigenous knowledge can be defined as a set of perceptions, information, and behaviours that guide local communities in their use of land and natural resources. Indigenous knowledge is created and sustained by local communities as a means of meeting their needs for food, shelter, health, spirituality, and conservation of their resources. Indigenous knowledge is usually adapted, and specific, to local ecological conditions and to a community’s social and economic situation and cultural beliefs. This knowledge can be both simple and complex and is not static. It evolves in response to changing ecological, economic, and socio-political circumstances and emerges from the creativity and innovation of community members, and the influence of other cultures and outside ‘western’ technologies.

**Background of study**

This paper will investigate the perceptions and attitudes of a group of high school learners towards indigenous knowledge systems (IKS) and the relationship IKS share with climate change education, weather predictions and cultural values. The study will also focus on the perceptions and views of high school learners of global, or ‘western’, scientific knowledge, and the Nature of Science (NOS) in relation to meteorological concepts. A further aim of this study is to determine the kinds of views high school learners of have of IKS as forming part of classroom instruction. Both the NCS and the newly drafted CAPS (2011) include IKS in the curriculum and assessment practices as part of the process of enhancing learners’ understanding of the Nature of Science (NOS), and their ability to make positive connections to the cultural knowledge that supports IKS.

**Problem statement**

Many high school learners do not recognise the value of cultural or indigenous knowledge. They do not understand the concept of IKS and how these systems relate to their everyday knowledge and experience. Everyday knowledge is important in the process of learners’ being able to make certain connections between the classroom and the outside everyday world. Teachers seldom use IKS argumentation-based instruction in classroom situations for the purposes of enhancing positive connections between the classroom and the everyday world of experience and knowledge. Seldom do learners get the opportunity to explore the nature of both indigenous knowledge and ‘scientific’ knowledge or to experience the value of their cultural knowledge inheritance, where knowledge is passed on from the elders through generations. Nowadays learners entertain themselves with modern technology such as the Internet, video games, and cellular phones, their highly advanced informational gadgets
rendering IKS an unpopular source of information. Such is the extent of the value learners attribute to these digital technologies, that interest in making a connection with IKS and their cultural values is practically non-existent. It is from this viewpoint that the research study and this paper were developed, with the hope of making teachers more aware and appreciative of an IKS argumentation-based instruction type of pedagogy to facilitate and engage learners in a better understanding and appreciation of cultural or indigenous knowledge.

Le Grange (2007) argues that in “Africa [including South Africa], schools are the sites where most learners first experience the interaction between African and Western worldviews”. Thus teachers working in these science contexts, especially in South African schools, need to be alert to “this type of interaction and understand the way it could complicate the learning process” (Le Grange, 2007). Much literature has been produced over the years about the experiences of (South) African learners in terms of the complications and difficulties of learning science in the classroom (Ogawa, 1986; Ogunniyi, 1987, 1988; Jegede, 1989; Jegede & Okebukola, 1989; Jegede & Fraser, 1990). However, despite this quantity of literature, and the “fact that indigenous knowledge systems reside in some form among the majority of South Africans, the topic has not been given the attention” in educational curriculum development policies “it deserves”, resulting in a lack of [South] African indigenous knowledge in “the discursive terrains of all learning areas/subjects” (Le Grange, 2007).

According to Schreuder & Le Grange (2002), many environmental problems in South Africa are related to the low level of environmental literacy inherited from the education crisis caused by the apartheid policies of the previous National Party government. Educational resources were, and continue to be, inequitably distributed and only benefit the minority of the population, while the majority continue to receive a poor education. This has resulted in widespread environmental illiteracy, lack of environmental sensitivity and the over-exploitation of natural resources. With the adoption of South Africa’s final constitution, human rights and social accountability have been enshrined and have been linked to environmental values. The 1995 White Paper on Education saw the need for the kind of environmental education that involves an active approach to learning (Department of Education, 2001b:3-7). The Revised National Curriculum Statement (RNCS) Grades R-9 (Schools) Policy of 2002 for Social Sciences envisages the kind of learner who can “develop an awareness of how to influence our future environment by confronting and challenging” environmental inequalities (R NCS, 2002). In both the RNCS and the NCS the learning outcomes promote the same values as does this research study: enquiry skills to investigate key concepts and processes, knowledge and understanding of the interrelationships between people, resources and the environment, and critical analysis of development issues on a local, national and global scale (Department of Education, 2002).

**Purpose of study**

The purpose of the study was to investigate the relationship between IKS and learners’ understanding of weather patterns. A related aim is to identify a possible correlation between learners’ attitudes and their understanding of selected meteorological concepts in geography.

This paper examines the role of Indigenous Knowledge Systems (IKS) in enhancing the understanding of weather patterns or meteorological concepts of learners in a Cape Town high school, the focus being on learners from ‘previously disadvantaged’ communities. The specific objectives of the study were to:

1. identify those indigenous practices and technologies which enhance learners understanding of weather/meteorological concepts
2. determine the extent of the use by teachers of indigenous knowledge versus scientific knowledge in enhancing learners’ understanding of meteorological concepts and
(3) identify the factors that limit the use of indigenous weather reading practices and technologies in the process of facilitating and enhancing weather forecasting concepts and understanding.

**Research questions**

We focused on the following questions in particular:
- What are grade 9 learners’ conceptions of IKS and weather phenomena?
- Is there a relationship between weather related IKS and a learner’s age, gender and socio-economic background?
- What current knowledge of IKS exists among grade 9 learners?

**Literature review**

Studies conducted by the NEETF (National Environmental Education Training Foundation) in 1990, claim meteorological theory based literature can make a significant difference to environmental education, and that learner’s benefit from the illustrations presented in this literature. The two studies reported that Environmental Education develops in learners a certain kind of skill that helps learners to better understand science content, such as meteorological concepts, 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 with local environmental conditions, learners make ‘real-world’ connections, thus making the material more meaningful, tangible and relevant, thus increasing learners’ interest as well as decreasing discipline problems (Battersby, 1999; Ernest & Monroe, 2004; Glynn, 2000; Krynock & Robb, 1999). The gains in learners’ achievements and motivation in this area are attributed to the nature of environmental literacy, which utilizes discipline integration, problem solving and hands-on activities (Glynn, 2000). The 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 theories accord with Vygotsky’s notion of constructivism in the process of which an individual learns or acquire 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. The study explored the application of both TAP and CAT in the context of classroom discourse dealing with selected meteorological concepts.
Dialogical Argumentation (DA)
Dialogical argumentation occurs when different perspectives are expressed on a subject with the hope of ultimately reaching consensus. The purpose is to persuade others of the validity of the claim through well-reasoned or well-grounded arguments rather than simply to win a case. Through dialogical argumentation, learners articulate their “reasons for supporting a particular claim and then strive to persuade or convince” others about the truthfulness of such a claim (Ogunniyi, 2008). Dialogical argumentation provides the critical “environment for learners to externalize their doubts, clear their misgivings or misconceptions, and reflect on their own ideas and those of their peers in order to arrive at a clearer and more robust understanding of a given topic than would have otherwise been the case” (Ogunniyi 2008).

Toulmin’s Argumentation Pattern (TAP)
In order to be participants in a scientific community, students and novices in particular, need to learn “how to construct substantive arguments to support their” position (Toulmin, 1958). Toulmin (1958) develops a Toulmin’s Argumentation Pattern that can be used “as a basis for characterizing argumentations in science lessons” (Pedemonte, 2005). Toulmin (1958) also suggested that the purpose of a substantive argument is to move from the data to a claim. For the purposes of this paper, and for the research study, this model was used to determine grade 9 learners’ conceptions and current knowledge of IKS around weather phenomena, and how IKS relates conceptually to environmental and climate change education.

Relationship between IKS conceptions and understanding of meteorological concepts
In the research study I proposed a methodological tool: Toulmin's (1958) Argumentation Pattern model (TAP), with Ogunniyi’s (1997) Contiguity Argumentation Theory (CAT), to compare and analyse the understandings and conceptions of grade 9 learners of IKS and of selected meteorological concepts in education research. The dialogical argumentation-based instruction was used to establish the characteristics of classroom argumentation and its relation to IKS and meteorological concept understanding.

Research shows that, only if argumentation is specifically and explicitly addressed in the curriculum, will students have the opportunity to explore its use in the Social Sciences (Kuhn, 1991). Much of science education has mainly focused on learners' understanding of science concepts in isolation and has used transmission learning as a way of achieving this, simply delivering scientific facts, rather than drawing on reasoning. Teaching methods that use argumentation and appropriate activities and teaching strategies in the Social Sciences or Natural Science class can achieve a wider range of goals, including social skills, reasoning skills and the skills required to construct an argument using evidence (Osborne, Erduran, & Simon, 2004a). Thus, according to this model, teachers who use argumentation during the teaching of a science subject need to adapt their teaching styles to include more dialogic approaches (Alexander, 2005) that involve students in class and lesson discussions, and to use teaching methods which encourage interaction with students in the process of fostering their argumentation skills. Thus, the function of “such dialogical space” is to enhance and promote the “process of re-articulation, appropriation and/or negotiation of meaning of the different world-views” (Ogunniyi, 2007).

As stated earlier, the study was 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 were chosen because of their amenability to classroom discourse dealing with phenomena about which learners might hold conflicting conceptions or worldviews. These frameworks provide the necessary context for inductive, deductive and analogical reasoning. They also accord with the Piagetian and Vygotskian notion of constructivism, which sees knowledge as constructed as one makes sense of the world around him/her. This type of reasoning can be use as an instructional tool with learners who are constantly interacting with their immediate and wider environments. In
the process of interacting with their immediate and global environments, substantial experiences are gained and individuals learn to relate to their environment in a sensitive and responsible manner.

The CAT construes learning as a dynamic process that entails a delicate balance between reason and emotion, body and mind and nature and nurture – all interacting in diverse ways to attain some level of equilibrium, ‘or in neural science terms, homeostasis, or more correctly, allostasis, since different activities demand different levels of homeostasis (Sapolsky, 1998).

Thus, learning includes many facets: association, dissociation, conflict resolution, accommodation, integrative reconciliation and adaption’ (Ogunniyi, 1988).

Methods
A survey was conducted among a randomly selected group of grade 9 learners in one secondary school in the Western Cape. A Learner Survey was administered to determine learner’s conceptions of IKS and weather-related phenomena. This was followed by a Conceptions of Weather (CoW) questionnaire to test learners’ understanding of meteorological concepts and attitudes towards their environment. The data collected through the various instruments were analysed in terms of appropriate quantitative and qualitative methods.

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 to determine “the consequences of a direct intervention into the status quo” (Ogunniyi, 1992:81).

Quasi-experimental Control Group Design
This research design is both quantitative and qualitative in nature, and takes the form:

\[ O_1 \times O_2 \text{ (Experimental group) } = (E) \]

\[ O_3 \quad O_4 \text{ (Control or Comparison Group) } = (C) \]

\[ O_1 \times O_2 \text{ = Pre-observations} \]

\[ O_3 \quad O_4 \text{ = Post-observations} \]

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

Procedure
In the first week of the third term, the Learner Survey and CoW (Conceptions of Weather) instruments were administered to 20 grade 9 high school learners. An even gender ratio of 10 male and 10 female learners participated in the survey. These learners were randomly selected and under no obligation to take part in the survey, which was conducted during a break in lessons.

The Learner Survey was the first to be administered because it was set up to test the perceptions of learners towards geography. The second to be completed was the CoW which tested the learner’s conceptions of weather. The two instruments were administered one week apart.

Selection of subjects for CoW
For the purpose of the CoW a group of grade 9 learners, ranging from 13 to 18 years from the same public high school in the Strand were selected. The school is situated in a socio-economically disadvantaged area in the Helderberg Basin. The group was selected on the basis of comparability with respect to:

- Learners taking the same subject and taught by the same geography teacher
- Formal class tests and reports
- Learners from within the same socio-cultural and economic background

Table 1 (below) gives a summarised overview of the background information of participants
### Table 1. Summary of the background information of the learners in the survey.

<table>
<thead>
<tr>
<th></th>
<th>Girls</th>
<th>Boys</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant Amount</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Grade level</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Age range (years)</td>
<td>13-15 yrs. (7)/ 70%</td>
<td>13-15 yrs. (8)/ 80%</td>
</tr>
<tr>
<td></td>
<td>16-18 yrs. (3)/ 30%</td>
<td></td>
</tr>
<tr>
<td>Home Language</td>
<td>Afrikaans (10)</td>
<td>Afrikaans (10)</td>
</tr>
<tr>
<td>Moslem religion</td>
<td>20% (2)</td>
<td>20% (2)</td>
</tr>
<tr>
<td>Christian religion</td>
<td>80% (8)</td>
<td>80% (8)</td>
</tr>
</tbody>
</table>

All the learners that participated in the Learners Survey and CoW Questionnaire came from the same community. The learners belonged to two different religious faiths namely the Christian and Moslem religion. We have noted that the Christian faith has a bigger representation than the Moslem faith in the selected school where the study was conducted. The Learners Survey and CoW Questionnaire were conducted in English, while the most common use of language for those who participated in the study is Afrikaans, however all participants had a good command of English. Both male and female subjects represented a wide age range between 13 and 18 years old. Amongst female participants, 70% were between 13 to 15, and 30% between 16-18 years old. Amongst male participants, 80% were between 13 to 15, and 20% between 16 to 18 years.

**Survey instruments**

**Importance of Geography**

Part 1 of the survey focussed on learner perceptions of the importance of geography as a subject. This questionnaire consisted of 20 questions, with possible answers to an item on a five point Likert scale (1 = strongly disagree, 2 = Agree, 3 = Uncertain, 4 = Disagree, 5 = strongly disagree). The survey questionnaire had five scales with acceptable reliability: Learning geography as a science (Item 2 ‘Learners are encouraged to participate in classroom activities’), Active learning (Item 5 ‘I like to visit places where I can learn more about the weather and the environment, e.g. Weather Stations’), Lesson structure (Item 8 ‘Geography lessons are worth the time and effort I put in’), Geography knowledge (Item 9 ‘Cold fronts bring much of the rain that South Africa needs’), Importance of geography (Item 13 ‘Knowledge of the environment is important for our survival on earth’). The questionnaire was administered in the first week of the third school term.

**Geography Classroom Environment**

Part 2 of the questionnaire looked at learners’ perceptions of their geography classroom environment. This section measured the learners’ attitudes towards a technology-rich learning environment and how they perceived geography needs to be instructed as a school subject. This section was administered at the same time as part 1 and consisted of 10 items along the same five point Likert scale: (Item 2, ‘There are sufficient textbooks and instructional materials for the learning of geography’), organization (Item 4, ‘The geography classroom has a lot of useful charts, maps and many useful learning materials’), satisfaction (Item 6, ‘The geography class is very lively because learners have opportunities to discuss topics about our environment’), open-endedness (Item 9, ‘I like working alone while doing my assignments in geography’), and material environment (Item 10, ‘We have no sufficient equipment, tools, maps, atlas, computers, etc. in the geography classroom’).

**Geography Knowledge**

Part 3 of the survey questionnaire addressed topics to inform the suitability of learner’s geography knowledge, the benefits to learning, and opinions towards weather phenomena.
This section also measured the learners' attitude towards geography and consisted out of 10 items on a Yes, No or Uncertain answer scale: global weather knowledge (Item 1, 'Geography subject can explain Climate Change'), environmental knowledge (Item 4, 'Geography makes me understand the environment and nature better'), practical knowledge (Item 6, 'I like the practical part of the geography subject'), geography classroom knowledge (Item 9, 'I can express my own ideas and opinions in the geography classroom').

**Conceptions of Weather (CoW) Questionnaire**

Quantitative research methods were introduced in the form of a Conceptions of Weather (CoW) questionnaire consisting of concepts dealing with meteorological literacy and IKS aspects for learners.

This questionnaire was administered two weeks after the Learners Survey questionnaire was completed. The same group that completed the survey completed the CoW-test.

Note: 1) Each question contained a Likert scale with a reason for answer as indicated below.
2) For question 6-10 did include a source of information choice (see below).

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
</table>
| Reason: .........................................................................................................................
| Source of information: Science, Religion, Personal View and Cultural View |

### Findings

Our results are reported in the context of our original questions, and combine the descriptive data with our survey data. Where survey and descriptive data (pre-test) were noted, we applied the CAT to describe the type of findings.

**Table 2** Sample questions used in CoW-test

1. Geography is interesting.
2. Using my indigenous knowledge to learn geography helps me to understand weather better.
3. I can use what I learn in a geography class at home and in my community.
4. I believe more in my indigenous knowledge than geography knowledge to understand the weather.
5. I am only interested in geography to pass my exams.
6. There is a relationship between what I learn in geography and weather patterns.
7. Cold fronts and bad weather (like heavy rain and strong winds) are caused by witches and traditional.
8. It is not necessary to protect yourself from bad weather, because it cannot kill you.
9. Geography explains the effects of cold fronts better than what I learn from home.
10. When cold fronts appear in the Western Cape we should be aware of bad weather patterns and heavy rain.
11. Without cold fronts Western Cape will be dry like the Kalahari Desert.
12. Cold fronts show that the sea gods are happy with us.
13. Unless we stop cutting down the trees and burning the veldt the rainfall received will fall drastically.
14. There is a relationship between global warming and increased flooding and too much carbon dioxide from the industries.

The excerpts below are representative of the learners' responses (direct translation) to certain items in the CoW questionnaire:

On Item 2, some girls responded:
I don’t always know what the weather would be. (L8)
To know everything about the weather is better than to understand that. (L9)
Sometimes I’m wrong but it help a little with geography. (L10)

On item 2, some boys responded:
No, if you don’t know geography how can you understand the weather. (L15)
Yes, it show all the countries and show the weather. (L16)
    To know what is going on with the weather. (L18)

On item 4 the girls (2) responses were:
I don’t believe in both. (L10)
On item 4 boys (3) responses were:
It shows on the news what is the weather going to be. (L17)
Their knowledge is better than ours. (L18)
Because indigenous knowledge will not show you about the weather. (L20)

The excerpts above suggest that most learner were never exposed to IKS in the field of geography and that there is no relation between IKS and their understanding of weather phenomena. Learners have little knowledge about IKS and the impact that it has on the global community. It is clear that very little indigenous knowledge was used at home by parents and other family members. If any IKS knowledge was used in daily traditions, it was never specifically noted by elders and others that it derives from a cultural system of IKS. This made it very difficult for learners to specify what is cultural knowledge or IKS when completing the CoW-test.

Not all learners completed the response section, and this resulted in only less than half of the total questionnaire that was administered being fully completed. This reflected that most of the learners do not show interest in reading and making time to answer questions properly, and that they are not motivated to study geography and the impact it has on their daily lives. Out of the 14 items that were presented in the questionnaire, only 2 were fully answered by all participants. Distorted conceptions towards geography as a subject can be picked up in many of their remarks that were given. Most of the reasons given to items did not relate to the choice of responses from the Likert scale. For example, an answer given by L01, such as “I don't like the stuff” to the item 1 question: “Geography is interesting”, clearly indicate the lack of exposure towards IKS. This indicates that our education needs to expose learner to IKS otherwise we will lose valuable cultural information with the type of behaviour that is currently demonstrated by learners.

In summary, there is no clear connection between IKS and weather amongst both girls and boys. One can clearly see that IKS does not carry meaning for these learners with respect to their social science knowledge.

**Recommendations and discussion**

Teaching and classroom practice need to focus on improving learners’ performances. This study recommends that teachers plan lessons that are high in IKS content that can promote critical engagement with indigenous knowledge, including disciplinary knowledge, to improve science problem-solving in the classroom. It will provide students with a better cognitive mindset to learn and understand important science concepts and processes in-depth rather than superficially, and to use these in ways to explain meaning, rather than simply reciting concepts.

**DAIM-model supportive classroom environment**

We recommend a dialogical instructional pedagogy in science classrooms, where learners will feel safe to take intellectual risks. With this approach, learners will be able to regulate their own academic behaviour and stay on task, teachers and students can be respectful towards each other but also engage with argumentation that draws on the beliefs, values and ways of knowing of different cultures. The DAIM approach is aimed to increase the
participation of all students and to build inclusive science classrooms, a connectedness to the world beyond the classroom – this would link school knowledge to student’s home or cultural knowledge and to events beyond the classroom setting.

In view of the above findings and limitations some serious consideration was taken of what kind of Science-IKS material should be included in the mainstream school science curriculum. In light of the new CAPS (2011) policy document the following recommendations were concluded:

**Recommendations towards curriculum design and development**

By working with colleagues and through discussion examining various dialogical instructional strategies, learning activities and curricular materials used in the classroom, thus viewing teaching in a more structured manner.

Further investigation into the authenticity of the teacher’s narrative and interpretation should be followed by interviewing learners exposed to the DAIM intervention.

**Recommendations towards teacher enrichment research**

Experimental or action research can be a worthwhile endeavour for a number of reasons:

Research and reflection allow teachers to gain confidence in their work by learning about themselves, their learners, their colleagues and their environment.

The DAIM method requires a lot of time, sacrifice and energy from the teacher but its benefits favour better classroom practice.

**Recommendations to design school science technology activities to enhance learners’ understanding in the use of wind and solar energy.**

Considering the specific aim 3.3 set out in the CAPS (2011) policy statement, schools need to invest in designing activities where learners will be able learn and interact with how weather (geography) affects our solar energy resources. Learners can then engage and experiment with solar energy and insulation to learn where photovoltaic power (solar panels) have the greatest potential. Learners can also investigate various geographic regions in their community, their climatic conditions and how they can influence solar-and wind energy potential.

Learners need to get familiar with the latest wind and solar technology to use the weathers natural resources to tap into a sustainable energy supply. Classroom activities and lessons can range from a 1 period lesson up to a week and learners can be assessed accordingly.

Activities can also include lessons where learners will learn about using the right type of materials in a home that conserves energy and the importance of building orientation and window size. Learners will be able to engage in activities to measure temperature changes in several thermal storage samples. By the end of such a lesson unit, learners have been exposed to and will appreciate the need to plan construction with proper materials. They will learn that simple measures, such as landscaping and installing thermal storage, make a big difference in energy consumption.

**Recommendations on the use of local IKS in schools:**

Indigenous knowledge is an important part of the lives of the poor, and is an integral part of local ecosystem management. IKS is a key element of the “social capital” of the poor; their main asset to invest in the struggle for survival, to produce food, to provide for shelter or to achieve control of their own lives. Indigenous knowledge also provides problem-solving
strategies for local communities and helps shape local visions and perceptions of environment and society. IKS is of particular relevance to the poor in the following sectors or strategies:

Midwives and herbal medicine.
Agriculture
Animal husbandry and ethnic veterinary medicine
Use and management of natural resources
Primary health care (PHC), preventive medicine and psycho-social care
Community development
Poverty alleviation

Indigenous knowledge is important, and respecting it:
is an essential first step for development projects,
allows better innovation and adaptation of technologies
adds to scientific knowledge
increases understanding between teachers and learners
increases the local capacity to experiment and innovate
empowers local people

School interaction with elders in the community

The Elders in the community can be approached to lead and deliver traditional protocol. They can be given a small offering in exchange for their commitment to invest their time and energy. They can be asked to lead gatherings such as parent meetings, social functions, fundraising events with prayer and ceremony. It is entirely appropriate to ask this of them. It may not be what we are familiar with at school, but the school community will soon realize the benefits of IKS and respecting of protocol and ceremonial practice.

Classroom interaction with elders in the community on the topic of IKS
The Elders can also be asked to do classroom visits and be part of IKS activities and share their indigenous knowledge with the learners. The Elders are well aware that any given group is there to learn from one another, and so investing indigenous wisdom and knowledge towards this endeavour would only benefit the learners. The Elders will share what is acceptable and provide appropriate caution for what they view as sacred knowledge that is only to be shared in the context of ceremony.

Conclusion
Geography is not a favourite subject for grade 9 learners at the school. Most of the learner’s current knowledge on weather and the environment is derived from school knowledge, very little knowledge was gleaned from an indigenous knowledge perspective. In fact, some learners had never heard of IKS. Teaching strategies should be initiated that showcase the importance of tapping into indigenous knowledge for easier and more relevant consumption of geography concepts.

References


Researching performance based assessment: authenticity in assessment activities and processes to support the development of learner capabilities

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Abstract
Over the last 25 years, researchers in the Technology Education Research Unit at Goldsmiths have been investigating ways of assessing learner capability, initially Design and Technological capability and latterly across a broader curriculum base. The focus of the research has been to find ways of understanding learners’ abilities in procedural settings and so has focused on creating authentic assessment activities that generate authentic evidence of capability. A considerable amount of this research has been in the context of high stakes summative assessment, developing valid, reliable and manageable assessment activities that can be used in the context of national assessments. An underlying model has been established - the ‘unpickled portfolio’ (Stables & Kimbell, 2000; Kimbell & Stables 2008) that structures short assessment tasks (between one and six hours) that generate portfolio-based responses in addressing problem/challenge based scenarios. Initially paper based and more recently digitally captured, these assessment tasks have been used with primary and secondary aged learners, across a range of curriculum areas and in contrasting national settings (including, in 1999, in South Africa; Stables et al., 1999, Stables & Kimbell, 2001).

This presentation will take a journey through a series of the research projects, from the first in the late 1980s where the initial approach was developed, creating dynamic, iterative assessment portfolios on paper, to the current projects that use mobile technologies to capture evidence of capability directly from learners as they convey their ideas and thinking through audio, video, text and image based tools. The journey will provide insights into the fundamental concepts behind the structure of the assessment tasks and portfolios – holistic performance, procedural capability, the iteration of active and reflective sub-tasks, authenticity in tasks and evidence. A framework illustrating how learning intentions can be mirrored with assessment intentions will show how constructive alignment (Biggs, 2003) can be achieved. Case studies from research projects will illustrate how the model has developed to be effective in formative, diagnostic, summative and evaluative settings. The case studies will also show how the model supports Problem Based Learning, enables collaboration and team work within an assessment setting, facilitates peer and self assessment by learners and enables a range of learning styles to be taken into account in collecting assessment evidence. It will also reveal how teachers and learners became involved in a radical approach to making assessment decisions – Adaptive Comparative Judgements (Pollitt, 2012; Seery et al, 2012). Finally, the presentation will attempt, through an exploration using validity, reliability and manageability as lenses, to comment on possible challenges and potential of drawing on the model in a Southern African context, particularly with regard to the theme of the conference and its focus on cultural and social relevance.
**Background**

Over the last 25 years, researchers in the Technology Education Research Unit at Goldsmiths have been investigating ways of assessing learner capability, initially Design and Technological (D&T) capability and latterly across a broader curriculum base. The focus of the research has been to find ways of understanding learners’ abilities in procedural settings and so has focused on creating authentic assessment activities that generate evidence of capability. A considerable amount of this research has been in the context of high stakes summative assessment, developing valid, reliable and manageable assessment activities that can be used in national assessments. However, the research has also shown the potential of the approach for formative assessment and a small number of projects have been developed that have placed an emphasis on this.

This presentation will provide an overview of the key aspects of the approaches to assessment that have been taken and will illustrate these by drawing directly on a small number of the projects. The initial project was undertaken between 1985-1991, funded by the UK Department for Education and sponsored by their Assessment of Performance Unit (APU) (Kimbell et al., 1991). It was part of a series of research projects that assessed 2% samples of the UK population in particular subjects and with specific age groups. The 2% sample meant that each age group assessed totalled in the region of 10,000 learners. The project we undertook was to assess the design and technological capability of 15 year olds in England, Wales and Northern Ireland. With the focus on capability, we were prioritizing assessment of process over content and, in our case, the process in question was the design process.

**The provenance of the assessment activities**

Rejecting linear models of process as being more about management than designing, the research afforded us the opportunity to explore alternative, more authentic perspectives. We developed a holistic and iterative view of designing that focused on active and reflective processes and the progressive relationship between these as a designer (or learner) progressed an unformed ‘hazy’ idea through to a well-developed prototype. (Figure 1)

![Image of the APU Design and Technology Model](image-url)

*Figure 1. The APU Design and Technology Model*
This model of process doesn’t deny features of more linear models (identifying problems, conducting research, generating and developing ideas, finalizing solutions, and evaluating). Indeed it recognizes that these ‘sub’ processes are present in large measure. But what it does reject is that they occur in a given, prescribed order. Rather it accepts that ideas are initiated throughout the process and that in moving towards ‘developed’ solutions problems are solved, research is conducted and judgments are made, driven by the desire to reach a prototype. This idea has resonance with the concept of design tasks as ‘wicked’ tasks, and idea introduced by Horst Rittell in the 1960s (Buchanan, 1995), that speaks to the nature of design tasks as indeterminate; with no clear, correct answer; in which the designer is operating on shifting sand, without all the knowledge required up-front; and managing ill-formed client expectations. In characterizing this complex process, Lawson (2004) described the process of designing as being like playing chess with minimal rules, but a clear intent. "Designing then, in terms of chess, is rather like playing with a board that has no divisions into cells, has pieces that can be invented and redefined as the game proceeds and rules that can change their effects as moves are made. Even the object of the game is not defined at the outset and may change as the game wears on. Put like this it seems a ridiculous enterprise to contemplate the design process at all.” (Lawson, 2004, p. 20).

This description presents design process as highly complex but at the same time captures the essence of its reality. It matches well with the view of process that we set out to assess. The challenge was to work out how we could assess capability evidenced through such a process, and to do so validly, reliably and in a managed way. An underlying approach was established through the initial APU research project – what we came to call the ‘unpickled portfolio’ (Stables & Kimbell, 2000; Kimbell & Stables 2008). We chose this label because of the way evidence of capability was generated and capturing in a short time frame – as opposed to more typical long projects where learners are steeped – or pickled – in the good ingredients of designing, learning and teaching experiences. This approach structures short assessment tasks (between one and six hours) that generate portfolio-based responses in addressing problem/challenge-based scenarios. The activities are structured through a series of sub-tasks that are choreographed to enable a dynamic relationship between active and reflective modes of designing. In the ‘high stakes’ assessment mode, standardisation is increased through the use of an administrator’s script that prompts each aspect of the activity and controls the time spent. All evidence of the work produced is recorded in a portfolio. Initially paper based and more recently digitally captured, these assessment tasks have been used in research and evaluation projects with primary and secondary aged learners, across a range of curriculum areas and in contrasting national settings, some of which will be drawn on to illustrate different assessment opportunities and challenges.

The importance of authenticity

From the outset of the original research project, we were concerned with authenticity. As has been described above, an immediate concern was for authenticity of process. This was based on the premise that if you want to know if someone is capable, then you need to be able to see them operating in practice. Put simply, if you want to know whether a learner can design, then you need to create a situation (or activity) in which they have the opportunity to design and, through this, to make explicit the evidence of their designing. So tasks, activities, challenges also needed to be created and, in parallel with our concern for authenticity in the process, we were equally focused on authenticity in the assessment tasks learners were presented with.
Broadly speaking, we have focused on two aspects of task creation, the context in which the activity is set and the way in which the activity is structured. With the former our belief is that the task should be embedded in a context that is relevant to the learner and is presented in a way that allows them to engage and take ownership of their task. In order to achieve this the task should be ‘issues rich’ such that there is complexity - the learner has plenty to get their teeth into and be challenged by. To address this we have introduced a number of ways of introducing and ‘fast forwarding’ learners to the starting point of a task using devices such as stories, short videos, scenarios etc.

Having created a starting point, the detailed structuring of the rest of the task is equally important if it is to provide authentic evidence of capability. It is also important that this evidence relates to the assessment criteria that have been set. In all of the research and development work on assessment that we have undertaken, there has been an undeniable link between the nature of the activity that the learners have been asked to engage in and the nature of the criteria that have been used to analyse their work. In essence, there is a reciprocal relationship. If the activity is authentic from a design viewpoint and at the same time provides explicit activity prompts that draw out evidence of the qualities under scrutiny, then both the activity and its assessment are likely to be valid. This relationship was first made explicit when devising activities to assess young children’s (5-7 year olds) technological capability (Stables, 1992) and we have found it to hold true in subsequent research.

Assessment activities, whether teacher-led or imposed by an external body, attempt to generate evidence of what a learner can do by prompting some kind of response. At the simplest level this might be asking the learner a question. This exposes the learning to the scrutiny of the assessor and is the first and most obvious purpose of evidence in an assessment setting. At a deeper level however if (in the eyes of the learner) the activity is sufficiently authentic, then the prompted display of evidence enables the learner also too to ‘see’ (probably for the first time) the evidence that they have just created. Reflecting on this evidence enables the learner to improve whatever they are doing. So not only do assessors gain insight into the learner, but so too do learners themselves. When done effectively, their thinking is laid bare for them to see and to benefit from. It is as if the performance is being observed in a mirror – and a mirror where both the teacher and the learner can see double-sided reflections that support both summative and formative assessment and also learning and teaching.

In this way we are creating constructive alignment (Biggs, 2003) between the desired learning and the evidence created for assessment. In formative assessment the model also provides for alignment between current and future teaching and learning and supports the learner in self-assessment. We have found that the more we embed and iterate active and reflective evidence prompts into an assessment task, the more we build meta-cognitive potential for the learner – helping them to make their own learning visible. We have explored ways of enhancing self-assessment towards sustainable assessment (Boud, 2000), for example by adding prompts for learners focusing on the following:

I was best at …
The easiest thing was …
The most difficult thing was
Today I learned …
I want to get better at are … (McLaren et al., 2006)
Figure 2. The mirror effect of effective evidence prompts

 Authenticity and criteria for assessment
If constructive alignment between learning and assessment is to be achieved, then the assessment criteria themselves need to be ‘authentic’ in terms of what they are attempting to reveal. In the original APU project the model of process we developed became important in identifying a framework for assessment. Our hunch was that we would need to consider three aspects as important:

- The inclusion of key elements of the process: identifying and addressing issues in the task; having a grip on generating ideas and developing solutions; appraising their thinking with a sound, critical eye.
- Interconnectedness of the iteration between thought and action.
- Viewing all evidence holistically.

The latter of these is particularly important as it allows us to see elements of the process at whatever stage they appear, rather than anticipating that they appear in a neat, linear fashion. It allows us to take an overall position on the learner’s achievement in the assessment task and then to look inside to identify the strengths and weaknesses within their work. In the APU project we explored this hunch empirically – we had 20,000 portfolios to analyse. 100 teachers worked with us as assessors and their first instruction was to look critically at all the work in a portfolio to see what the learner had done, what they had tried to achieve and how they had approached this, and then to make a holistic, professional judgement about the overall quality of the work. The teachers were supported in making this judgement through a
training process and through having ‘exemplar’ scripts (portfolios) that had already been assessed by the research team. Following this initial judgment, they were provided with a rubric that asked them to make progressively smaller, more focused judgements. Counter-intuitively, the smaller and more focused the judgments became, the less statistically reliable they were found to be. (Kimbell et al., 1991)

This holistic approach to assessment, initially developed as a research tool, has been explored, augmented and developed through a range of our projects and has been shown not only to support the authenticity in the process, but also act as an important professional development tool for those engaged in the assessment process – as will be illustrated by the case studies that follow.

Capturing capability – learning styles and designing styles, going digital

Having set the learners an assessment challenge, learner responses are collected through a portfolio, structured through a series of prompts. In the initial project, the portfolio was designed as a large (A2) sheet, folded into a booklet that progressively unfolded as the learner moved through the assessment activity, as shown in Figure 3. This design allowed learners to have sight of their work as it progressed, rather than hiding it from themselves by turning a page.

Figure 3. The unfolding booklet of the “unpickled portfolio”

The principle behind this unfolding booklet has been retained through a series of projects, each time being customized to meet the needs of new project. The booklet encourages learners to draw and/or write, as they see fit, and has proved to be an effective way not just of
capturing evidence of capability, but also revealing different styles of designing that have also related to learning styles (Lawler add date). In recent research we have moved the portfolio into digital mode through the use of mobile devices such as PDAs, mobile phones and netbooks. This move has afforded even greater opportunity to take account of learning and designing styles and preferences, as learners have been able to document their process through the task using a combination of text, drawing, audio, video and photo tools. This has provided both flexibility and speed in the ways in which ideas and thinking can be documented. For example, to convey an idea and the thinking behind it, a learner can:

draw on the PDA screen and then annotate by writing freehand on the screen;
photograph a sketch model and annotate by adding a voice memo;
use the video facility to ‘fly through’ a sketch model, or show it in action, using voice-over;
draw an idea on paper, photograph it and add a voice memo;
draw and annotate an idea on paper, then photograph it;
photograph a sketch model, and then sketch or annotate freehand on top of the photo image on screen;
any combination of the various techniques above.
The increased range of ways in which learners can capture the evidence of their ideas and their thinking has further enhanced the authenticity of both the activity itself and the evidence of capability that is generated through it.

Case studies
The case studies that follow have been chosen to illustrate how the model has developed to be effective in formative, diagnostic, summative and evaluative settings. They show how peer and self-assessment can be facilitated and how learning styles can be taken into account. They also illustrate how collaboration and teamwork within an assessment setting can be enabled. In addition to the APU project, the following three projects will be drawn on to exemplify these various aspects.

The North West Province Technology Education Project Evaluation (NWPTEPE) (1999). As part of C2005, this project (funded by UK DFID and SA PROTEC) was a three-year pilot of a Technology Education curriculum in a number of schools in the North West Province of SA. The project was conducted with Years 10, 11 and 12 and ran from 1997 to 1999. The DFID also commissioned TERU to evaluate the impact of the pilot. We were required to assess the capability of learners engaged in pilot schools in comparison with learners in schools that had not. The assessment activities, based on the unpickled portfolio model, were designed to take account of the features of the pilot. This meant that the assessment activities explored learners understanding of materials and processes, energy and power, and communications technologies through problem-based approaches and teamwork. The evaluation compared 10 pilot with 10 non-pilot schools. In each school 18 learners were involved in the assessment activities. In addition teachers, headteachers and learners were interviewed about their experiences. To support capacity building, six South African fieldworkers contributed to the evaluation. (Stables et al., 1999)

Assessing Design Innovation (2002-2004). This project, funded by the UK Department for Education and Skills, was prompted by a concern for the way in which assessment was driving creativity and innovation out of the D&T curriculum. The focus of the work was on developing high-stakes assessment activities for the GCSE (16+) assessment in D&T. The activities were created in conjunction with practising teachers and the examination Awarding Bodies. The unpickled portfolio approach was developed into a six-hour activity focusing on
creativity and innovation. The project included two important innovations. The first was the use of “critical friends” (Costa and Kallick, 1993) within the assessment process and the second was the introduction of 3-D modelling, evidence of which was captured through photographs taken throughout the activity and pasted as a digital storyline into learners’ portfolios. The activities were adopted as a model of “constrained assessment” and now feature in the menu of assessment activities available within GCSE exams in D&T. (Kimbell et al., 2004)

e-scene (e-solutions for creative assessment in portfolio environments) (2004 & continuing). The e-scene Project built directly from Assessing Design Innovation and explored further the possibilities of digital capture in performance-based assessment activities. A system was created that enabled assessment activities to be designed and presented to the learners through mobile devices such as PDAs, mobile phones and netbooks. The work undertaken by the learners, is documented through text, voice, video, photo and drawing and is synchronised dynamically to a web space while the learners are working. Assessment of the work takes the idea of holistic assessment one step further to allow for Adaptive Comparative (pairs) Judging, explained below under Making Assessment Judgements (Pollitt, 2012). The e-scene project has explored the development of dynamic digital portfolios and pairs judging in different disciplines, across age groups, and in a number of different countries including Scotland, Australia, Ireland and Israel. The Israel e-scene project, entitled Assessment in my Palm, is exploring the use of e-scene for formative and summative assessment in ongoing class projects. (Stables & Lawler, 2011)

Creating authentic contexts
When assessing performance capability, engaging learners at the outset of an assessment activity is important. Two examples are given illustrating quite different approaches to doing this.

In the APU project this was challenging for two reasons: first the whole activity had to be conducted in 90 minutes and second the learners were being assessed on the ‘design and technological capability’ before a subject of that name had been created within the UK curriculum. This meant that many students were being assessed on something they didn’t study in school. In order to ‘fast forward’ the learners into the assessment activity, we created a series of short (6 minute) videos that presented issues-rich snapshots into a particular scenario. For example, one focused on the challenges of the elderly, carrying heavy food shopping, reaching to store it in low and high cupboards, opening packaging and preparing and cooking foods. In addition, the learners were put into ‘role’ – they became part of a design team with individual responsibility for certain phases of development.

The NWPTEPE presented a different challenge. First we had to create a task that had relevance for learners living in South African townships. Second we had to create level a playing field for the learners who had not experienced the radical curriculum of the NWPTEP. Next in addition to assessing procedural capability, the task had to provide opportunities for learners to show understanding of materials and processes, energy and power and communication technologies. Finally the starting point had to set the learners up to work in teams. Our approach to this was to create a scenario around safe transportation of medicines to rural communities in hot climates where road conditions are poor. We presented the task as a challenge for a team of six, made up of three pairs of learners, each pair taking on an element of the challenge. The structure of the task is presented in Figure 4.
These two approaches, the videos and the team challenge scenarios, allowed us to quickly transport the learners into settings where design challenges and opportunities were opened up and quickly got the learners up to speed. They also resourced the learners with understandings of issues to be addressed whilst leaving space for the learners’ own ideas and experience.

**Structuring the activities**

The APU project set the blue print for structuring an activity through iterating active and reflective prompts to learners. This approach is illustrated here by the Assessing Design Innovation project. Figure 5 provides an overview of the six-hour activity. The ‘light fantastic’ brief created a model for further challenges, created by experienced teacher-examiners. As with all of our tasks, once the challenge has been introduced we encourage learners to articulate, through drawing and/or writing, whatever vague and early ideas they have. This has typically been a solo activity, but in Assessing Design Innovation while each learner was working on their own task, they sat within a supportive “critical friend” group of three. The first interaction between the three is shown in Figure 5 as steps 3, 4 & 5 – swapping initial ideas for development & critique. Once ideas have been returned and reviewed by their original owner, individual development gets underway. Here, for the first time, we introduced 3D ‘sketch’ modelling. We had become acutely aware through our work with teachers that, if they were freed from the burden of assessment and asked to focus entirely on supporting creative responses, teachers provided the resources and encouragement to enable learners to engage in 3D modelling at a very early stage of designing. The response from the learners was impressive in terms of developing ideas. But as models were developed, re-worked, destroyed and re-built, the evidence of designing was being lost. Our solution was to take digital cameras and printers into the assessment space and photograph the designing six times during the activity. The images were immediately printed and returned to the learners so that a photographic storyline of their development was set down almost in real time. The total activity was broken into two sessions of three hours. Towards
the end of each we prompted peer and self-assessment within each group of three. The final stage involved each learner ‘fast forwarding’ their ideas to show what the finished solution would be like if it were taken to production.

‘LIGHT FANTASTIC’ TASK
A light bulb company wants to minimise packaging waste and extend the product range they offer. They want a new range of light bulb packaging that people won’t throw away.

Your task is to come up with exciting ideas for light bulb packaging that people won’t throw away because it transforms into interesting lighting features & structures.

By the end of the activity you must have produced
- a working light bulb package containing everything for the lighting feature;
- an assembled lighting feature;
- a persuasive argument for your product to attract purchasers.

Outline structure
1. read task to the group and establish what is involved
2. explore a series of ‘idea objects’ on an ‘inspiration table’ and in a handling collection designed to promote ideas for transformation
3. put down first ideas in a designated box in the booklet
4. swap work within team - for further development by team mates
5. work returned to ‘owner’ to consider which ideas to pursue
6. teacher introduces the modelling/resource kit
7. learners develop their ideas through drawing – and/or through 3D modelling
8. learners reflect on the user of the end product and the context of use, before continuing with development
9. at set intervals, learners pause and throw a ‘questions’ dice, e.g. “how would your ideas change if you had to make 100?” Answers recorded in their booklet
10. approximately every hour photos of modelling taken to develop visual story line of evolution of design ideas
11. end of 1st morning, learners reflect on own and team members work
12. 2nd morning starts with celebration of work from day 1 using ‘post-it’ notes to highlight ‘best’ idea, ‘wackiest idea’ biggest problem and ‘next steps’.
13. prototype development continues
14. hourly photos and pauses for reflective thought continue
15. final team reflections on each others’ ideas and progress
16. learners ‘fast forward’ their idea - what it will look like when finished

Figure 5. The structure of the Assessing Design Innovation tasks

It was the introduction of digital cameras into the assessment activity that caused the initial shift towards developing the digital ‘unpickled portfolio’. As suggested above, our primary reason for the photographic record of modelling developments was to capture evidence. What we hadn’t bargained for was the significant impact the action had on the learners’ design thinking. Once the first photo had been taken, they started to anticipate subsequent photos – using them as staging posts and as an impetus to push their progress. This dual value – of capturing evidence for assessment and supporting the development of the ideas – encouraged us to explore the further use of digital tools for both the assessment and development of capability.
Supporting learning styles
A contentious issue within assessment, particularly in relation to equity of assessment approaches, is the extent to which any assessment is biased by the response mode that is required from the learner. Whilst in a teaching context it is important that learners work from the strength of their preferred learning style to develop broader ways of learning and communicating, in the context of assessment it is more beneficial to the learner, and arguably more equitable, if they can provide evidence through whatever mode allows them to best demonstrate what they know, understand and can do. Data collected from both teachers and learners (through questionnaire and interviews) has shown how valuable a range of digital communication tools can be in this respect. Once a learner has access to documenting in ways other than writing, they become liberated. This has been particularly apparent where learners with Special Education Needs have been involved and where learners are given choice in the tool for documenting. The following quotes from teacher interviews in the Israel e-scape project illustrates this well.

I have 14 pupils in the group all of whom have special needs. … When I told the pupils they were going to use this computer-based system they were so happy. They all have problems with reading and writing. Because they use computers in their everyday lives with email and Facebook and the Internet they find using computers very comfortable. When I told them they were going to work with computers in the biology lessons they were very excited. They felt that it would give them a chance to succeed and that they could work without my help. For then the computer is something friendly not at all frightening. For them to take pictures and to print and write on the computer is not as difficult as writing from the blackboard they feel more comfortable with it. (Biology teacher)

“Each child has their own strengths and can choose the skills that are fit for them. … We think of what is the benefit and the ways we can open their minds … We found that for each mission [sub-task] we could give two alternative functions, two tools, and the children can choose which one they want to use. This is very good. One likes to draw, one likes to take a photo” (Geography teacher).

Some ways in which learners have utilised the digital tools for documenting has surprised us – the most extreme example being a learner chose to present the evaluation of their work as a Rap. Learners will also reveal insights more honestly than in a more traditional setting. The following transcription of an audio evaluation by a learner illustrates this well.

“Well, I can’t really further develop it because we are finished, but if I did have extra time I would sort out the cogs because it just looks like something that has fallen out of the sky and hit the ground at a very high speed and has managed to fall and glue itself together. It is just wrong. I don’t know how I did it. It is just a disgrace. I would have sorted that out, yeah, basically that is what I would have sorted out.”

Students have seen the value of having access to the digital tools very positively. In each project we collect user data through an end of task questionnaire. Chart 1 provides an overview of the responses we have typically received from learners.

Teamwork and collaboration
Teamwork and collaboration has featured regularly in our assessment activities – for example the use of “critical friends” illustrated through the Assessing Design Innovation project. At times collaboration has taken a supportive role only, at times it has been considered in the assessments being made. This was the case in the NWPTPE where we wished to see the impact team working had on performance. Consequently, in addition to assessing evidence of technological procedural skills and the application of knowledge, we also sought evidence of
‘team working’, as characterised through “group decision making, addressing the whole task, amalgamation of ideas, supportive interaction”. (Kimbell & Stables 1999, p. 7) Through the evaluation of the pilot we also found considerable further benefits of team working, particularly the positive attitudes engendered between girls and boys. (Stables & Kimbell, 2001)

![Chart 1. Learner evaluation of e-cape assessment activities](image)

**Different disciplines**

While the original APU project was focused on secondary (Year 11) D&T learners, we have explored authentic assessment approaches from six to seventeen year-olds and in a number of different subjects. While the approach needs customising in each setting, there is remarkable transferability where the focus of the assessment is on procedural capability. Two examples from science provide insight into the approach and its value.

Science e-cape was a focused pilot within the main UK e-cape study (Kimbell et al., 2009). It set out to explore the potential of e-cape to assess scientific capability – the procedural dimension of science. The assessment activities were 3 hours long and, as with D&T, were structured through a digital portfolio and managed through an administrator’s script. The e-cape science team created activities that enable learners to:

- demonstrate curiosity about phenomena in the world around them and find explanations,
- link direct practical experience with scientific ideas,
- experiment with and model ideas to develop and evaluate explanations,
- exercise critical and creative thought,
- so that their solutions are rooted in evidence,
- and enabling their scientific ideas to improve the quality of life.

As an example, in one activity the learners acted as scientific advisers to the road planning committee of the Local Council. They had to design and conduct a series of experiments on force / speed / impact / deceleration in order to advise on traffic regulations that might apply to roads around schools. The outcome of the activity was an evidence-based, scientific report of physics phenomena.

Both the activity and the assessment of its outcomes mirrored the value of the approach that we witnessed in other projects and led to a spin-off project in primary science. (Davies et al., 2012)

**Making assessment judgments**
So far, the case studies have shown how evidence for assessment is generated and collected. As has been explained earlier, our approach to making assessment judgements has broadly adopted a holistic model. This has involved us first creating a rubric that provides a set of characteristics of holistic performance and then identifies the key elements within this, each of which also has a set of characteristics. The rubric used for the Assessing Design Innovation project is shown in Figure 6 as an example rubric where the emphasis is on assessing creativity and innovation.

Figure 6. The assessment rubric from Assessing Design Innovation

Assessors are then asked to review the whole of a learner’s portfolio and make an overarching holistic judgement, guided by the rubric and often also by exemplary material. The assessors then review the work again, looking for evidence of the first element – in this rubric, *having ideas*. Assessors are encouraged to look for evidence at every stage of the work, not just at the outset. Having identified the evidence, they make a judgement about the quality of the work, using the rubric descriptors as a guide. This process is repeated for each element. What is important is that, whilst closer scrutiny of the work may result in the holistic judgement being changed, it is because the assessor’s understanding of the work has improved, not because a numeric relationship is made between the holistic judgement and the judgements against each element. We believe this approach provides an authentic judgement – a view that is echoed in the comments from the following teacher-assessor.
One of the major strengths of holistic judgements I see is its flexibility… in which you can give credit to students for what they have actually done rather than whether they are able to “tick the boxes” to match a set of assessment criteria. (Kimbell et al., 2009).

This process has been taken one step further in e-scape through the use of Adaptive Comparative Judgement. This is a system that operates online, within the digital portfolio database, that identifies pairs of portfolios for assessors to judge holistically, and through multiple judgements being made on the portfolios, creates a rank order of performance. Statistically, this system is extremely reliable and is also seen as being fair.

The judging system feels to be fair; it doesn’t rely on only one person assessing a single piece of work. It removes virtually all risk of bias…. It feels safe knowing that even if you make a mistake in one judgement it won’t significantly make a difference to the outcome or grade awarded to the student as other judges will also assess the same project. (Kimbell et al., 2009) We have also found considerable ‘added value’ in the impact that engaging in the judging process can have on both teachers and learners. Teachers have found it valuable to look at work of multitudes of learners that they don’t know, as a way of understanding how different learners have responded to the assessment challenge. For learners the process appears even more powerful. Two different settings exemplify this. The first was with undergraduate students where it provided a valid and reliable approach to peer assessment. (Seery et al, 2012) The second was a pilot within the main e-scape project, where a group of Year 10 learners who had undertaken the assessment activity, were trained to act as assessors and experience the judging process for themselves. Not only were their judgements consistent with the adults, they found the exercise highly illuminating because of the insights gained from assessing each other’s work. They commented that they felt better prepared for future work. (Kimbell, 2012) This pilot opened up the potential for a more democratic approach to assessment where learners could join in the process alongside their teachers, even in the context of high stakes assessment.

The value of the approach for Southern Africa
This paper has presented an account of a particular approach to assessment - authentic assessment through performance based portfolios - that has attempted to address issues of reliability, validity and manageability within a system that is fair and equitable in the assessment of procedural capability. The approach also aims to supports the development of the learner’s capability. But is it an approach that has value in the context of Southern African schools education? More so, considering the theme of this conference, does it have cultural and social relevance?

This question is best answered by those working in Maths, Science and Technology education within Southern African schools, and this is a debate for the conference. However, I will make some comments towards exploring this area, and do so by considering the question through the lenses of validity, reliability and manageability and within my minimal understanding of these challenges within Southern Africa. I am aware from reading that there are real tensions at play, for example, highly aspirational curriculum documents that are being implemented without adequate resources (World Bank, 2008). Conceptually, the approach to assessment that I have presented provides a structure towards constructive alignment between teaching, learning and assessment – something that has equal priority in Southern African curriculum documents that promote Outcomes Based Education (OBE). However, there is evidence that achieving this is problematic.
If the implementation of new curricula demands new forms of assessment but the implementation of assessment practices and instruments lags, the curricular changes have little or no chance to make it into the classroom. It is a common observation and result of numerous researches across SSA that the lack of alignment between curriculum intentions and assessment, and the quality of assessment and examinations remains a major obstacle for curriculum implementation at large. (World Bank, 2008, p.62)

Even when used for high stakes assessment, through the emphasis on authenticity, our model takes a learner-centred approach, seeking to capture evidence of genuine, procedural capability. This too has resonance with Southern African curriculum aspirations, but also appears to be in tension with actual practices, where it isn’t clear that assessment of anything other than factual content is valued. Stears and Gopal (2010), highlight this issue whilst exploring alternative assessment practices in science with Year 6 learners, making the case that assessing learners through reference to the understanding that is shown through their everyday, life experiences may be an important for-runner to developing and assessing knowledge of science concepts. Referring to Donald, Lazarus & Lolwana, (2002) they comment that “Unfortunately, the value departments of education, learners and the general public attach to marks do not bode well for an approach where learners are assessed by interpreting their actions, attitudes and emotions” (Stears and Gopal, 2010, p.595). The World Bank report makes a somewhat starker statement claiming that Modern curricula in SSA formally aim at learning outcomes like comprehension, application of knowledge, methodological and social competencies, and problem solving. Current assessment and examination practices are limited to the recapitulation of memorized facts. (World Bank, 2008, p 57).

In discussing the “Teach for examination success” issue, the World Bank report (2008) highlights a further tension in the value that is placed on different assessment practices, stating “assessment and qualifications that only test for methodological and social competencies lack the achievement of clear exit skills, and have proven to lead to an “anything goes” attitude in the classroom.” (World Bank, 2008, p. 58). This prejudicial attitude towards qualitative aspects of learning and assessment is not unique to Sub Saharan Africa. But it does pose a problem when considering validity in assessment practices. It also links to issues of reliability. Where reliability is linked to an expectation of right or wrong, yes or no, answers and ‘clear exit skills’ then qualitative judgments are viewed with suspicion. The focus on this perception of reliability in assessment appears common in the Southern African context, but again, this is in conflict with curriculum aspirations for learner centered learning and OBE. Perhaps the statistical reliability that has been shown through our approach to holistic judgment can be used here to support more qualitative practices, which are surely more socially and culturally appropriate.

A further issue that I would consider to be important and challenging is the extent to which assessment is teacher dominated. This can be seen even within curriculum and assessment documents where assessment is seen as something that is ‘done to’ not ‘with’ learners. This issue has been highlighted by Beets and van Louw (2005, 2011). Our research is supporting an approach which is not only learner centred but actively seeking ways of further democratizing assessment, and there are indications that this would be welcomed by educators in Southern Africa, but could be a challenging concept for policy makers. An inescapable issue raised by our approach is the very real challenge of manageability, and particularly the importance of managing resources, including teachers’ time to understand, adopt and implement new initiatives. The specific issue raised by the value we have seen of
making digital resources available cannot be ignored. Again I am aware of the contrasting perspectives presented, for example by the e-Learning Africa 2012 report (Isaacs & Hollow, 2012) that provides a view of African youth as ‘digital natives’ and highlights the positive impact of ICT on learning, and the challenges highlighted in the World Bank report even of insufficient textbooks, amongst other scarce resources. One point that we have made consistently about our own approach is that pedagogy comes first; technology can then act as an enhancer. The fundamental principles and approaches we have taken are not reliant on new technologies. The world does not stand still and the challenge is to make sure that, as technologies are more available, they support rather than replace good pedagogic approaches to teaching, learning and assessment.

My comments may seem simplistic, but I feel the approach I have outlined has strong potential to support social and cultural relevance in assessment practices, but the challenges in doing so are many. In writing this last section I can’t help but reflect back on the brave, radical curriculum development that took place through the NWPTEP in the late 1990s and how this was welcomed by teachers and learners alike. The issues raised here have parallels to those raised through the NWPTEP, not least by the learners themselves who felt hugely empowered to learn through problem solving, in groups, supported rather than dictated to by teachers; who were demanding that other teachers in their school adopted the same pedagogies that their technology teachers used; who engaged with the assessment activities wholeheartedly, but who felt that the lack of ‘validation’ of technology by a ‘formal’ examination at matriculation marginalised the positive experience of technology education that had been afforded.

References
Top of Form

528


A model for Africanising higher education curriculum: A quest for educational relevance

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Abstract
The purpose of this paper is to suggest a model for indigenising university curriculum (MIUC) in the higher education context with regard to indigenous technologies as part of indigenous knowledge systems. The paper was motivated by the tendency that I came across while reviewing existing corpus of scholarship, that higher education institutions are aware that the curriculum that they offer to African indigenous students is predominantly Western-based. They thus are aware that this orientation needs to be transformed. It is most probably the how to transform the curriculum that the institutions remain stuck with. Thus, my contribution with this paper is to suggest a model that helps provide an answer to this ‘how’ – informed by the existing indigenous practices that were explored through scholarship review. I believe that this provision of a model will begin to spark discourses in the direction of integrating or ‘embedding’ indigenous technologies in the mainstream Western-based curriculum. I start with critiquing the Western linear approach to curriculum engagements and practices, proceed to explore existing indigenous practices, then propose the model in question.

Background
This is a literature study-based paper the purpose of which is to explore internationally and Africa-based existing models, strategies or efforts by scholars, tertiary institutions or states to africanise curriculum to provide guidelines to produce a model for the higher education curriculum in South Africa. African universities’ student population is predominantly indigenous. Ironically, these universities’ curricula are still dominated by Western epistemologies and knowledge systems. African universities are thus faced with the challenge to africanise or indigenize their curricula in order to better and relevantly service indigenous African students. But they do not know where and how to start with the process of africanisation. Thus, to fill this gap, the exploration referred to above will be undertaken in order to recommend a model of africanising the higher education curriculum. The exploration of existing models, strategies or efforts is intended to abase the recommended model. Makgoba (in Viljoen & Van der Walt, 2003) perceives africanisation as the process or vehicle for defining, interpreting, promoting, and transmitting African thought, philosophy, identity and culture (also see Msila, 2009). Africanisation also entails a serious quest for a radical and veritable change of paradigm so that the African may enter into genuine and critical dialogical encounter with other pyramids of knowledge (Banda, 2002). Africanisation resonates with indigenisation due to the African masses being indigenes to Africa whose education is contested in this paper. Therefore, I use the terms Africanisation and indigenisation interchangeably in this paper.

Contesting the Western canons by educational terms is at stake in this paper. Thus, I will undertake this inquiry to confront the status-quo that seems hegemonic in tertiary education – the Western dominance to curriculum that further disadvantages indigenous African students and advantages non-indigenous students. A Western curriculum approach does a disservice to indigenous African students by pushing for a positivist notion that claims that only the
Western knowledge systems can be justified as part of the curriculum. It excludes other forms of knowledge systems. According to Michie (1999), government policies in the Western countries may have no longer been assimilationist, when curriculum has certainly not followed suit.

Curriculum transformation can only be realised if indigenised standpoints are put at the centre of the curriculum (MLCek, 2009). Furthermore, transformation can be achieved only if there is attitudinal change to recognise indigenous culture as a positive resource (MLCek, 2009) rather than a stumbling block or curriculum overload. The definition of curriculum that I prefer for the engagements in this chapter is Marsh’s and Willis’ (2003), which states that curriculum is the questioning of authority and the searching for complex views of human situations. It follows that this paper concerns itself with curriculum inquiry because the issues that I raise hit squarely on the curriculum that higher education institutions purport to offer. In the context of the above definition, the stance that I take in this paper is that of questioning colonial approaches to curriculum, which do greater disservice to indigenous African students, and recommend a model solution towards transforming higher education curriculum. Higher education institutions are aware of the “what” question, i.e. they know that something is definitely wrong about the relevance of their curriculum to the indigenous masses in Africa, and that it is inevitable that they transform it. The “how” question is what many institutions do not know yet. The recommended model will answer the “how” question.

The route that this paper takes is to first explain the theoretical parameters guiding the line of thought. This will be ensued by condemning the non-relevance of colonial approach to education, consideration of indigenous knowledge as an alternative to Western knowledge, and the role that higher education institutions can play in the promotion and advancement of indigenous knowledge systems. Then I will proceed by exploring models, strategies or efforts on indigenising curriculum existent in Africa and those outside of Africa. A close study of these models, strategies or efforts will ultimately enable me to recommend a comprehensive MIUC.

Critical ontological and indigenous standpoint theories (Kincheloe, 2006) guide engagements in this paper – contesting curriculum and the learning thereof as well as its application should be relevant to indigenous students/people (Choy & Woodlock, 2006). In keeping with Vygotsky’s notion of constructivism, learning is culturally and socially contextualised (Kincheloe, 2006; Choy & Woodlock, 2006). Critical ontological theory promotes self-discovery and power of self-emancipation. Its aim is to revive an awareness of indigenous students’ confidence and their urge to believe in their indigenous identity without self-pity.

Indigenous knowledge is creating awareness even in some Western contexts, awakening what was historically a disinterest in it. For instance, it is starting to become more widely valued in areas like environmental management, quantum physics and ecological knowledge (Michie, 1999). In the academe, worth noting is a Unisa-based example. A law lecturer, Taylor (2010), has initiated the embedding of African indigenous law in the law curriculum. Two modules on indigenous knowledge have now been embedded, even though Taylor still feels that this is far not enough considering the 40 module-based law curriculum. Taylor’s strategy is tailored in the context of the response of Council on Higher Education’s (2009) response to the Soudien Report on the research carried by the Ministerial Committee (Department of Education, 2008).
According to Kincheloe and Steinberg (n.d., p. 22-23) and Semali and Kincheloe (1999, p. 33-38), research and curricular use of indigenous knowledge systems (IKS) can yield the following benefits to the academe:

- Rethinking of educators’ purposes in terms of the existence of multilogicality, disclaiming intelligence through a positivist mind-set that is opposed to logocentric knowledge boundaries.
- Focusing attention on ways knowledge is produced and legitimated, not in a neutral, noble, and altruistic manner.
- Encouraging construction of just and inclusive academic spheres, characterised by hermeneuts and epistemologists in uncovering the etymology (origin) of knowledge inclusions and exclusions, notions of superiority and inferiority, racism, and ethnocentrism.
- Producing new levels of insight, to realise the importance of indigenous knowledge and its value about health, medicine, agriculture, philosophy, ecology and education.
- Demanding that educators become researchers and push education to achieve more rigor and higher pedagogical expectations.

The next section discusses the role that higher education institutions can play in promoting and advancing IKS as an alternative to Western knowledge systems (WKS).

A call on universities to indigenise their curricula

According to Agrawal (n.d.), focus on indigenous knowledge clearly heralds a long overdue move, seeing it as an alternative shift from the Western knowledge towards people’s development. Agrawal thus argues that ignoring people’s knowledge is tantamount to ensuring failure in development. Scores of scholars in the likes of Odora Hoppers (2005), Kawooya (2006), El-Ayoubi (2007), Ocholla (2007), Msila (2009), Hauser, Howlett and Matthews (2009) and Mapara (2009), have been disquieted by the colonial approach to the education of indigenous communities. Michie (1999, p. 7) relates in this instance, the stance taken by the Inuit educators in the North West territories of Canada to develop an Inuuqatigiit curriculum by involving elders for their guidance and information. Its goals are to maintain, strengthen, recall and enhance Inuit language and culture; to enhance unity within Inuit groups; to create a link between the past and present; to encourage the practice of Inuit values and beliefs; and to encourage pride in Inuit identity to enhance personal identity.

African intellectuals and governments are blamed for their adoption of colonialism, sending the roots of oppression even deeper. Odora Hoppers (2005) laments the silenced fellow African intellectuals for not staying on course to forge africanised concept of education and curriculum. She accuses the African government’s trading of africanisation of education for nationalist goals and being uncommitted to support the postcolonial africanisation agenda. The post-1970 political instability has entrenched the relativisation of academe and simply left no room for intellectuals to occupy public space, sending scores of Africa's best brains into exile, self-effacement and invisibility, self-imposed marginalisation, fawning adulation of power, jail or death (Mkandawire in Odora Hoppers, 2005, p. 11). Odora Hoppers (2005, p. 31) observes that right from the first conceptualisation of the African university, universities were conceived of as institutions for producing manpower to indigenise the civil service following independence. She cites Mkandawire who argues that the conception of the social contract that universities had is today assessed by African scholars and found not only to be a gross understatement, but also to represent a complete misunderstanding of the tasks that lie ahead.
Bearing in mind the above claims, it is clear that the university is yet to wean itself from the Western notion of educational provision. But what makes the transformation effort even tough is African governments, who are blamed for detouring from the course to facilitate the Africanisation agenda. They regulate universities’ programmes especially with regard to knowledge production for economic reasons, denying them to exercise their transformative mandate. As a result, universities are perceived as agents of governments that perpetrate marginalisation. They are included for numbers to claim subsidy, but they are excluded in terms of knowledge construction. They are being ostracised due to their culture being defined as backward, primitive and having nothing to offer educationally. This is a deliberate oversight to degrade the educational importance of culture when indigenes have to be served. This matter suggests one thing: higher education can no more escape the claws of the challenges that it faces – to balance qualifying students to be absorbed into the corporate market and to be answerable to equipping the majority African students with relevant knowledge production to fit well in the indigenous communities that they hail from. According to Odora Hoppers (2005, p. 9), two pertinent issues that face higher education have to do with service to the communities and answering relevantly to the economic call. This calls for the critical review content and organisation of curriculum that are structured in ways that differ dramatically from students’ homes and out-of-school experiences (Semali, 1997).

As such universities are being called upon to play a leading role in terms of fairness to knowledge production when it comes to serving indigenes. They have to reorientate themselves to ensure that they offer relevant programmes to African students. Njiraine, Ocholla and Leroux (2007) conducted a qualitative study on auditing IKS in South Africa. Their aim was to explore IKS policies and legislations, structures and systems, activities and research trends. They purposively sampled policy documents and applied snowball sampling to interview key informants in this regard. Their findings confirmed the existence of policy that guides activities around IKS, and intellectual property framework; established structures which include the Advocacy and Policy Development Directorate which participates in international structures dealing with intellectual property, e.g. World Intellectual Property Organisation; etc. on the other hand, Hauser et al (2009) acknowledge the progress made by the Canadian universities like Trent University and Breton University in embedding indigenous knowledge in their curriculum compared to the greater extent to which indigenous students are being underrepresented in the Australian higher education system.

As stated above, academic institutions, being research institutions, are about knowledge construction. This being the case, it should also be mentioned that their research activities are informed by the primary world, i.e. the authentic contexts where they conduct their empirical research. Given the realities of the microcosmic cultures that they research, there is much room to diversify their approaches towards their research to ensure that they co-research with indigenous custodians of knowledge that they research. Linear methodological approaches and skewed research, coupled with positivistic distorted representations of indigenous communities can no longer hold. In this sense, academic institutions can really reposition themselves in unravelling the realness of IKS which have for decades suffered self-aggrandized colonial hegemony.

IKS are a reality characterising the philosophy and survival of indigenous communities. We can no longer look to the Western universalised knowledge for our educational endeavours. Thus, in keeping with IKS’s contestation in this section, they should be considered as an
alternative to Western knowledge forms or claims. As a result, the next section explores existing approaches on attempts to indigenise higher education curriculum.

**Approaches as attempts to indigenise the university curricula**

Let me start this section by first explaining the criteria that I used to decide on the contexts the approaches of which I explored:

- I chose three contexts in Africa and three outside of Africa. The choice was informed by the scope of this chapter and my belief that this was a reasonable number to satisfactorily enable me to draw a pull of ideas from for the proposed model.
- The models/strategies/efforts could have been developed by higher education institutions, national governments, individual researchers or philosophers, research groups, or even indigenous communities who showed commitment to indigenise the curriculum.
- The contexts from which these models/strategies/efforts were explored should have a colonial experience and history.
- The choice of the contexts outside Africa was not based on any particular principle, e.g. First World or Second World contexts.

**Africa-based approaches**

**Culture Product Indigenisation Process (Culpip) Model**

Obikeze (2011) suggests a Culpip model based on culture manifesting in terms of products. Culture products are human devices, formulations and techniques, tangible or intangible which fulfil some need or provide some service for humankind in a given environment. Tangible devices include knives, fishing nets, machines, bombs, electronic devices, etc. Intangible devices include songs, jokes, ideas, skills, methodologies, organisations, etc. These culture products are organised according to technologies and goods and services. Three categories of technology include material, social and communication technologies as follows:

- **Material technology:** tangible devices and implements, e.g. bows and arrows, ploughs, typewriters.
- **Social technology:** theoretical formulations, procedures, know-hows and ways of doing things, e.g. methodologies, techniques, organizational and management skills, bookkeeping and accounting procedures.
- **Communication technology:** purely symbolic devices that serve as vehicles for communication, e.g. language, signs and symbols, drumming.

Goods and services technologies are any products of human activity that are usable to satisfy human needs or meet societal ends. These are sub-divided into material, social/services and intellectual goods explained as follows:

- **Material goods:** physical finished products and consumables, e.g. soap; food items like maize; houses, ornaments, aeroplanes, and television sets.
- **Intellectual goods:** non-tangible culture objects in the context of ideas, abstract concepts, names, terminologies, cognitive knowledge and idioms.
- **Social goods and services:** non-material, intangible end products of human social activities, interaction processes and role-relationships, e.g. values, norms, customs,
motherhood, priesthood and friendship, social services like concerts and plays, football games, health and healing systems and belief systems.

From the Culpip model Obikeze proposes a process which should be guided by closely interrelated, largely dialectical and interactive activities grouped into six essential steps:

- **Step 1:** Establish a Culture Products Transformation Centre/Institute based on purpose, function, mandate and research.
- **Step 2:** Self-examine and evaluate traditional culture products according to self-examination and evaluation.
- **Step 3:** Engage constructively about fracturisation of foreign and indigenous culture products on the basis of fracturisation, generation of new forms of culture products, integration of new culture products into the university curriculum, and protection, empowerment and popularisation of indigenous culture products.
- **Step 4:** Generate new forms of culture products including production and reproduction of pure indigenous culture products; creation and reproduction of new hybrid culture products; and creation and reproduction of adapted culture products.
- **Step 5:** Integrate the new culture products into the university curriculum through engineering of the curriculum.
- **Step 6:** Protect, empower and popularise indigenous culture products to ensure their survival by empowering them legally, socially and psychologically.

Developments about efforts to indigenise curriculum in South Africa

Efforts by South Africa are policy-based efforts. Mosimege (2004) relates efforts, which started as an audit project of indigenous technologies between 1996 and 1998 by the Portfolio Committee commissioned by government. Later on indigenous technologies as a concept was reviewed for IKS. The audit project involved CSIR and nine local universities. This audit project led to the formulation of the IKS Policy by the Government’s Ministerial Task Team in 1999 (Mosimege, 2004; DST, 2004). The executive summary of this policy (DST, 2004, p. 9) states that the IKS Policy is an enabling framework to stimulate and strengthen the contribution of indigenous knowledge to social and economic development in South Africa. The main drivers of this policy include (DST, 2004, p. 9):

- Affirmation of African cultural values in the face of globalisation;
- Practical measures to develop services provided by indigenous knowledge holders and practitioners;
- Underpinning the contribution of indigenous knowledge to the economy; and
- Interface with other knowledge systems.

The executive summary of the policy further lists the required institutions and legislative provisions in order to realise its implementation (DST, 2004, p. 9):

- A IKS Advisory Committee that reports to the Minister of Science and Technology;
- A development function that includes academic and applied research, development and innovation in respect of IKS;
- A record system for indigenous knowledge and indigenous knowledge holders, where appropriate, to pro-actively secure their legal rights;
- The promotion of networking structures among practitioners, to be located in the DST; and
• Legislation to protect intellectual property associated with indigenous knowledge, to be administered by the Department of Trade and Industry.

The second bullet above implicates the role of and accords universities a formal mandate to be proactive in the protection and promotion of IKS, especially in the area of research.

The IKS Policy was approved by Cabinet in 2004. This led to the establishment of the National IKS Office (NIKSO) in 2006 located in the Department of Science and Technology (DST).

The South Africa Constitution protects principles of democracy, social justice and equity, equality, non-racism and non-sexism, human rights and human dignity that it includes. These principles underpin the values upon which the national education system is premised (DST, 2004:17). In fact, IKS is one of curriculum principles (Department of Basic Education: Curriculum and Assessment Policy Statement, 2010) and this implicates higher education curriculum. It is asserted in the White Paper on Science and Technology that sustainable technological capacity requires a transformed, vibrant and effective educational system (DST, 1996). On the other hand the White Paper on Arts, Culture, and Heritage views education as part of culture and acknowledges that culture itself is transmitted through education (Department of Arts, Culture, Science and Technology, 1996). But the vibrant effective educational system can be realised through accommodating indigenous cultures and their domains of knowledge, techniques and technologies. According to DST (2004), it is critical to ensure that the national education strategy is synergistic with and nurtures indigenous knowledge.

Models outside of Africa
Efforts by Queensland University of Technology (QUT)
These efforts are related according to McLaughlin and Whatman (2007). These efforts resulted from the launching of the Australian Reconciliation Movement triggered by the 1990 Royal Commission into Aboriginal Deaths in Custody. The 339th recommendation in the report states, that all political leaders and their parties recognise that reconciliation between the Aboriginal and non-Aboriginal communities in Australia must be achieved if community division, discord and injustice to Aboriginal people are to be avoided. QUT launched its reconciliation statement in May 2001. In the statement QUT committed itself to sustainable reconciliation between indigenous (Aboriginal and Torres Strait Islander) and non-indigenous Australians. To this QUT committed over half a million dollar grant to start a project on embedding indigenous perspectives (EIP) in its teaching and learning. Four faculties applied and implemented the project. These include QUT Carseldine (School of Humanities and Human Services) and Creative Industries, Law and Justice Studies, Faculty of Health and Faculty of Education. QUT recognised that the Oodgeroo Unit, which is the centre for Aboriginal and Torres Strait Islander student support, teaching, research and community engagement, should be the first point of contact for conceptualising each project. I only describe the project by the Faculty of Education.

The Faculty of Education re-conceptualised its Bachelor of Education (BEd) programme offered to all pre-service student teachers. It followed an outcomes-based approach as a model of design and implementation of the project like other faculties did. Unlike the other faculties, the Faculty of Education introduced a core unit as part of the foundation suite of units. In this instance, an indigenous academic from the Oodgeroo Unit was seconded to spearhead the conceptualisation and design of the unit of study entitled: Culture Studies:
Indigenous Education. This unit was informed by indigenous knowledge and experiences both theoretically and pedagogically. The unit became compulsory for all pre-service student teachers from 2003. The outcome of the project was that the Oodgeroo Unit ultimately produced two internal monographs which informed the BEd and teacher practitioner attributes developmental process. Another outcome entailed the creation of a Learning Circles professional development programme for the staff of the Faculty of Education which was convened by the academic staff from the Oodgeroo Unit. The case study conducted reported that the unit was challenging, informative and shifted students’ thinking or positioning of themselves and indigenous Australians.

Sagu-llaw SIKAT
Abejuela III (2011) reports the strategy by a tertiary-type school by the Buckidoron tribe Philippines archipelago. The Philippines archipelago has 7107 islands. It spans a total area of 300 000 square kilometre with approximately 8 million people 75% of which comprises of the eight major ethnic groups. The remaining 25% comprises different ethnic groups and indigenous tribes. Americans established the public school system in the country with no effort to integrate indigenous knowledge. English was dominant as a language of instruction. Native languages have never been encouraged. A handful of indigenous schools exist solely due to efforts of the tribal leaders, often with minimal government support, if any. Asian Council for People’s Culture (ACPC) introduced Schools for Indigenous Knowledge and Traditions (SIKAT) programme. The declaration contained in ACPC states that indigenous education is a basic right of all indigenous people founded on the life-ways, traditions, worldviews, culture and spirituality of the native community. It is a pathway of education that recognises wisdom embedded in indigenous knowledge. SIKAT is undergirded by the principles of ownership, emancipation, cultural diversity, environmental sustainability, community centredness, rootedness in day-to-day reality and recognition.

Sagu-llaw SIKAT trains indigenous para-teachers. Students attend class once a week on Fridays. For the other days of the week they teach kindergarten in their respective barangays (communities). The school uses four languages as mediums of instruction – English, Tagalog, Cebuano and Binukid. The school’s curriculum runs over four years:

1st year covers:
- Orientation on Bukidnon which is a Higaonon cultural language, and the Philippine Constitution and the IPRA law;
- Principles and methods of teaching;
- Literacy and numeracy skills development and traditional songs, dances and arts; and
- Introduction to community development.

2nd year covers:
- Intricacies of the Bukidnon language which include lexicon, grammar and usage;
- Bukidnon culture and migrant culture to promote understanding between people and lowlanders;
- History, institutions and heroes of the tribe, that is things that student teachers would have not learnt in government schools;
- Ethnic songs, stories, dances and art and craft; and
- Vocational, social and economic aspects of community.

3rd year covers:
• Different chants, stories, legends and customary law of the tribe;
• Ethnic cultural practices, beliefs, rituals and ceremonies and knowledge systems which incorporate community development and environmental conservation and protection;
• Traditional political leadership and the Philippine justice system in order to protect the tribal members from exploitation from migrants and lowlanders; and
• Training to teach Philippino and English as second language.

4th year covers:
• Philippine and world history, vocational art and craft, ancestral domain; and
• Cultural research.

Sichuan University
Tillman and Salas (2011) write on the efforts by Sichuan University to embed indigenous knowledge in its curriculum. Sichuan people are the Chinese indigenous community characterised by diverse ethnic minority cultures. These cultures belong to the nationalities of Zang (Tibetan), Qiang, Yi. The community lives on mountainous areas. The majority of these ethnic groups are rural and still keep their traditional livelihoods and cultures alive. They and some Han adventurous settled many centuries ago to become herders and farmers developing original indigenous technology and knowledge systems. The attempts by the Han adventures to civilize these indigenous groups were resisted. They were determined to maintain the accumulated wisdom as key to understand nature in promoting endogenous development.

As a result scholars and lecturers of Sichuan University opted to include the theory and methods of indigenous knowledge and cultural affirmation in the academic curriculum with an option to specialise as an applied researcher. They started by conducting a ten days curriculum design workshop. They invited some selected graduate and postgraduate students of Sichuan University to this workshop. They designed Masters courses with content selected from the literature in the fields of ecology, history and anthropology (culture studies) and translated into Chinese for graduate students. The course was embedded in a general philosophical-theoretical framework of knowledge as a human intellectual effort to explain reality. The course enabled participants to do self-reflection on their own knowledge to come closer to other ways of thinking reality. It included the following modules:

• Concepts of indigenous knowledge;
• Methods of indigenous knowledge, including the design of fieldwork plans;
• Rights and ethics of indigenous knowledge;
• Pedagogical (teaching) concepts related to indigenous knowledge based on experiential learning; and indigenous knowledge approaches defined in the context of learning at Sichuan University in terms of time frames, structure and content.

The workshop was guided by the process and method of active participation, non-compliance to conventional teaching, epistemological foundations, visiting professors only introducing concepts, visualisation, mental mapping and interpretation, and documentation and analysis of own experiences.

The following were the outcomes of the workshop:
• Work plan to introduce indigenous knowledge in the different disciplines. This consisted of curriculum for the first year, proposal writing for fieldwork and thesis writing during the second year and third year of the Masters courses.
• Necessary tasks to be performed, like translation of the reader, collection of Chinese material on indigenous knowledge of ethnic minorities, documentation of own research experiences based on the indigenous knowledge practiced during the workshop.
• University club on ethnic and cultural studies.
• Identification of students with ethnic origin, who may become intercultural facilitators in the future, as they know the language, have a village background and will eventually be motivated to engage in village work with their own ethnic group.

A model for indigenizing the university curriculum (MIUC)
Within the scope of this chapter, I propose this model using my college, i.e. College of Education (CEDU) and Master in Education (MEd) as examples. A model for Africanising curriculum that I envisage for the College of Education (CEDU) and the University of South Africa (Unisa) is depicted in figure 1 below, followed by its description. I reckon this suggestion is in support of Unisa’s vision: “Striving to become an African university in the service of humanity”.

Stage 1: Establish the College of Education IKS Office (CEDU IKSO) and staff and equip it
• Appoint an IKS practitioner (preferably an associate or full professor) as a curriculum transformation project leader (CTPL).
• Appoint an IKS practitioner (preferably a senior lecturer with a doctorate) as assistant to the CTPL.
• Appoint at least one representative from all the departments in CEDU to serve on the CEDU IKS Committee chaired by the project leader and participate in its projects. These representatives should either be engaged in IKS or be interested in churning their careers towards this field. The main reason for this is that they are envisaged to drive curriculum transformation that embeds IKS in their departments.
• Appoint a research assistant and administrative assistant to be responsible for data collection and analysis, and administrative duties respectively. The research assistant should have a know-how of data collection and analysis.
• Equip CEDU IKSO with required furnisher and technology for the project leader, his assistant, research assistant and administrative assistant as per the needs of CEDU IKSO.

Stage 2: Curriculum Review Project
Project Level 1: Project Proposal for Funding
• Conceptualise a research project proposal to research a national culture to be used as a compass to draw up the curriculum.
• Write up a project proposal plan for funding in accordance with the criteria of the identified funding agency – target funding institutions capacitated by government to support IKS projects, e.g. NRF, DST and other national and international funding organisations like UNESCO’s education wing, World Intellectual Property Organisation (WIPO), etc. Unisa’s research office can be of help in identifying relevant funders and the application format.
The proposal should identify the research as an ethnographic or action research for purposes of spending more time in the community of identified culture and for active participation of the community members as co-researchers.

Also highlight the proposal’s relevance to the goals of Unisa’s Institutional Operational Plan (IOP), and its ODL and MIT nature.

Submit the project proposal to the relevant approval structures in the CEDU and Unisa at large, and finally to the funding institution/agency.

**Figure 1.** A model for indigenising the university curriculum (MIUC)

Project Level 2: Research a National Culture

- Implement the project proposal in Project Level 1 above. Add onto the bit of literature survey in the project proposal by embarking on intensive literature survey on IKS. This should also include IKS Policy and IKS Audit Report.
• Spend no less than six months of ethnographic or action research (or other IKS relevant methods) in the field (community of culture identified above) to engage community members as participants in the study and gather data. The interest should fall onto the culture itself and its practices and products.

• Identify key informants within the community being researched (preferably elders) who can provide rich data on the cultural history, products and practices. Plan well for the use of indigenous languages in engagements with the community, and their translation.

• Write a report on the research conducted, which can be used as a guideline for drawing up the curriculum.

• In the report highlight aspects that can be used to preserve the culture and aspects that can be blended with the conventional (Western) culture.

Project Level 3: MEd curriculum review

• From the existing MEd programme, select at least one specialisation per department which can be reviewed to infuse IKS and to be piloted.

• Conduct programme review workshops which are participatory in nature, that is, encourage stakeholder participation.

• To these workshops invite key stakeholders. Select from the IKS experts in the community, MEd students, NIKSO representatives, key players who were commissioned by government to for the IKS audit, and internal structures like Centre for African renaissance, Thabo Mbeki Institute of Leadership, College of Law which has already taken initiative to infuse IKS in its curriculum.

• From the workshops produce a work plan to introduce indigenous knowledge in the sampled specialisations. Plan around the first year Research Proposal Module, second and third years. The first year on Research Proposal Module (RPM) must specifically be spent on literature survey and community based visits. Select a sample of local students for a guided visit. The rest of other students should make their own arrangements in their own settings, but follow the guidelines set down by the CEDU IKSO. At the end of their first year all students should present a supervised approved research proposal plus portfolio of evidence. The purpose of a portfolio of evidence is to showcase the students’ accumulated experiences based on the literature survey and visits. The portfolio should include but not limited to biographical information, learning journal, resources and artefacts.

• The second to third years should be characterised by fieldwork visits and the writing up of chapters.

Stage 3: Pilot Reviewed Curriculum

• Roll out the reviewed curriculum as a pilot IKS infused curriculum.

• Closely monitor the process of implementation and evaluate it.

• Conduct a debriefing workshop.

• Involve representatives of stakeholders who were part of the review workshop, particularly students and indigenous experts.

• Re-plan (if necessary) and re-implement the pilot IKS curriculum.

• Monitor and evaluate the process again.

• Conduct a debriefing workshop.

Stage 4: Full Scale IKS Infused Curriculum Implementation
Informed by the pilot IKS infused curriculum, embark on the overall curriculum implementation – all MEd programmes in all departments.

Maintain and manage the programme.

Embark on ongoing research with teams that include MEd and DEd student projects.

Establish CEDU’s IKS Club for cultural and social activities that advocate IKS (ubuntu, products, etc.)

Be proactive about programmes on other levels:

- Already plan for a DEd with specialisation in IKS by building onto this model as a template.
- Consider cascading the IKS infused curriculum down to the undergraduate programmes.

**Conclusion**

In this paper I have attempted to make a case for embedding IKS in higher education curriculum. To this effect I theoretically abased the paper, presented the indigenous knowledge perspectives as an alternative to the Western dominant curriculum, critiqued the function of universities and called on them to indigenise their curricula. The heart of the paper lies in the the exploration of existing IKS-based approaches in Africa and beyond, which enabled me to design MIUC. MIUC provides the ‘how’ to embed IKS within higher education curriculum. Of course, based on their contexts, higher education institutions should critically apply their minds in considering MIUC. For that purpose the model can be modified in the process of its adoption to better suit their respective contexts. It thus befits to call it a working model towards curriculum transformation to ensure the embedment of IKS in higher education institutions. This model has been conceptualised for postgraduate curriculum with specific reference to the MEd programme. Institutions should strongly consider modifying and adopting it for the undergraduate programmes as well. They should also advance it to the DEd programme so that students carry their specialisation right through.

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A diagnostic teacher practice framework for science teaching: a case of projectile motion

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Abstract
Projectile motion can be a challenging topic because of misconceptions associated with it. Strategies have been identified and suggested to ensure that teachers teach the topic such that it is accessible to students. So it was not surprising that some teachers in one of the districts in the Gauteng province indicated that the topic is difficult to teach. Moreover according to the Department of Basic Education students perform poorly on the topic. Even though teachers attended some in-service training to improve their content knowledge which was perceived to be the source, they still held the perception that projectile motion is difficult to teach. Therefore it is the purpose of the paper to increase the tools for fundamental resources for in-service training for teachers who perceive certain science topics as difficult to teach. The paper also intends to add into the debate on teacher practices in science teaching. The diagnostic teacher practice framework was developed to analyse the classroom practices and to determine teaching difficulties. One of the grade 12 Physical Science teachers who perceived projectile motion to be difficult to teach was identified. The teacher was interviewed prior to the teaching of the topic and after which he was also observed teaching the topic. Then the framework was used to analyse data and the findings showed that the framework assisted in identifying the teaching difficulties. We also suggest areas for further research.

Keywords: teacher practice, teacher knowledge, instructional strategies, discourse, projectile motion

Introduction
There are various frameworks for example the IRF (initiation, response and feedback) framework (Carlson, 1991). The framework was improved to IRFRF which is part of the analysing science teaching interactions framework (initiation, response, feedback, response and feedback) by Mortimer and Scott (2003). It was further improved to II-ER (Identification, Interpretation-Evaluation, and Response) framework by Louca, Zacharia and Tzialli (2012). Even though each framework is different from its predecessor we found the frameworks focusing more on the teacher – students interactions. Some frameworks give more emphasis on the teacher who elicit and construct students’ ideas. This is a weakness claimed by Louca (2012) as the reason for their new framework which gives more emphasis on the contributions by students as well as that of the teacher. Our framework is not totally different to the other frameworks but it builds on those frameworks. It is designed for the teacher who perceives certain science topics to be difficult to teach. The framework gives emphasis on the teacher with a view of finding ways to help the practicing teacher to teach better. This is so because our framework draws from not only the analysis of interactions but also taps into the instructional strategies the teacher uses, teacher knowledge and teacher accountability. We acknowledge that some may view the focus on the teacher as a weakness but we are of the understanding that it is important to also focus on what the teacher use, does.
as well as his intension either short term or long term whilst teaching a particular cohort in order to have a positive impact on the classroom practices. We also accede to the fact that a focus on teachers who have teaching difficulties is not to be viewed as limiting because studies and experiences in science teaching have shown that teachers can perceive some topics of the science curriculum as difficult to teach (Gunstone, Mulhall and McKittrick, 2008 & Tao and Gunstone, 1999) and teaching difficulty is not something easy to articulate (Geelan, Wildy, Louden and Wallace, 2004). Due to the nature of the subject, difficulty in teaching can happen when teachers fail to make their classroom practices assist them to achieve the end. In science teaching the end refers to achievements by students, meaningful learning, developing inquiry skills and problem solving skills in students (Abd-El-Khalick and Akerson, 2009 & Staver, 2006). The framework should be of assistance to the practitioners in teaching for example; school head of departments, deputy principals, subject advisors and other service providers who are expected to assist teachers in their classroom practices. We say this because it will add into the resources of micro foundation for in-service support by introducing the classroom practice diagnostic framework as one of the tools that can be used to investigate teaching difficulties in the teaching of science. This is so because there is impervious lack of micro foundation resources (Jita, 2004) for in-service support with a focus on classroom practice, yet experiences and observations show that much focus on the in-service trainings has been on improving the teacher’s subject matter knowledge in physical science. Furthermore, the framework has aspects of paramount importance which we are of the view that they are intertwined and needs to be developed independently and jointly to positively influence performance (Staver, 2006) through meaningful making by students (Chin, 2006).

A case of Projectile motion

There have been many studies on projectile motion or force and motion for example (Graham, Berry and Rowlands, 2012; Bayraktar, 2009; Dilber, Karaman and Duzgun, 2009; Prescott and Mitchelmore, 2005; Tao and Gunstone, 1999 & Gilbert and Zylbersztajn, 1985). Some of these studies showed the development of the concept of force and motion, misconceptions associated with force and motion, conceptual change as a strategy to change the misconceptions and theories that misconceptions also develop during teaching as previous studies considered them as ideas developed outside the science classroom. Other studies suggested strategies for example computer modelling as an explanatory framework that will make the learning of projectile motion accessible to students. Yet there are still teachers who have knowledge that there are misconceptions in projectile motion and have studied physics topics in their undergraduate and some in their post graduate studies, who still perceive projectile motion as difficult to teach in one of the districts in the Gauteng province in South Africa. This is not surprising if one notes all the studies that have been done in projectile motion about ways of teaching it and illuminating misconceptions. These teachers attended in-service training to improve their subject matter knowledge because it was assumed that it is because they lack the subject matter knowledge. A point which Rollnick, Bennett, Rhemtula, Dharsey, and Ndlovu. (2008) highlighted that some teachers who were trained in the former colleges had subject matter knowledge which was not more than the last level of high school in physics. Amidst all the strategies to assist in-service teachers with topics they perceive difficult to teach we are of the view that there is a need to focus on the classroom practice hence the development of the diagnostic teacher practice framework (DTPF). Through the framework it should be possible to identify at a microscopic level what the teacher does which makes him have a perception that projectile motion is difficult to teach.
The diagnostic teacher practice framework

The framework was developed from the following theoretical perspectives, the PCK, teacher accountability and classroom interactions frameworks. In the DTPF, the following domains of the teacher’s pedagogical content knowledge were focused on: teacher’s content knowledge of projectile motion, knowledge of students’ understanding of projectile motion and the knowledge of the context in which projectile motion is taught. These domains of teacher knowledge are intertwined with the teacher’s interactions and discourse in the classroom and the instructional strategies he/she used in the teaching of projectile motion as well as his accountability focus. The DTPF is expatiated next.

Figure 1: The diagnostic teacher practice framework
The teacher’s content knowledge meant the amount and organisation of subject matter knowledge in the teacher’s mind with a focus on projectile motion. Knowledge of students’ understanding referred to the teacher’s knowledge of the prior knowledge the students need to learn projectile motion, linguistic abilities, and interests of the students as well as misconceptions students might have of projectile motion. The knowledge of the context referred to all the contextual aspects that could influence the teaching of projectile motion. The contextual aspects included some of the following: resources in the classroom, socio-economic background, the curriculum, time available and class size.

The instructional strategies were made up of epistemological perspectives, didactics, explanatory frameworks and activities. Epistemological perspectives referred to how a teacher demonstrated through practice how knowledge was acquired. This was identified by focusing on the two approaches of epistemology namely rationalism and empiricism. Didactics referred to the traditional teaching methods like lecture, demonstration methods which the teacher used. Explanatory frameworks or representations were the analogies, models and/or illustrations the teacher used to make the learning of projectile motion accessible to students. Activities implied problems, demonstrations, simulations, investigations or experiments which the teacher used to help students comprehend the content.

In the classroom interaction and discourse the emphasis was on the talk by the teacher to/and with the students. The focus was on types of science classroom discourses, patterns of discourse, communicative approach and teacher questioning. Types of discourses were the authoritative, dialogic and reflective discourses. During authoritative discourse the teacher used traditional methods like the lecture method and focused only on science concepts without acknowledging alternative conceptions. Dialogic discourse referred to the discourse wherein the teacher used a variety of methods to help students comprehend the targeted concepts. The teacher also acknowledged alternative concepts and prior-knowledge and involved students more in the lesson. In the reflective discourse the teacher taught through negotiations than transmission of new knowledge. The teacher also acknowledged alternative concepts and prior-knowledge. The focus was on student’s thinking.

Patterns of discourse engrossed on the initiations of the teacher as well as the feedback he/she provided for example the IRF (initiation, response and feedback) pattern. The communicative approach was attentive to the way the teacher communicated with students to make them comprehend the targeted ideas and concepts. Four classes of communicative approach namely interactive-authoritative, non-interactive-authoritative, interactive-dialogic and non-interactive-dialogic were focused on. Teacher questioning focused on the teacher’s orientation when asking questions. That is if he/she asked questions to evaluate, to construct understanding or to develop a lesson.

Accountability referred to the three accountability themes namely the accountability to the system, students and subject/discipline. In the accountability to the system the teacher focused on the results by emphasizing the completion of the syllabus within a short period of time and also emphasizing the pass rate in the subject. Accountability to the subject had the focus on the instructional strategies the teacher used in engaging students to make meaning out of the content presented. Lastly accountability to the students referred to the teacher’s endeavour to focus on all his/her students by using their personal experiences outside the classroom in the teaching and learning process. The focus was also on the students’ abilities.
and language issues so that all students participate in the science classroom.

**Methodology**

Our case Mr. Manngo was qualified to teach Physical Science and was the head of department for Physical Science and Mathematics at his school. He had more than 15 years teaching experience of teaching Physical Science. He perceived projectile motion as difficult to teach. Mr. Manngo was not alone as the same sentiment was also shared by other members of the cluster. The same notion was also evident during the grade 12 marking session wherein projectile motion was one of the topics wherein students did not perform well and the Department of Basic Education (2010) in the moderators report apportioned the blame on how the teachers teach the topic. Mr. Manngo was interviewed before the teaching of the topic and after the teaching of the topic. He was also observed teaching the topic to the grade 12 students. The purpose of the interviews and observations was to determine what makes the teaching of projectile motion difficult. The DTPF was used to analyse the classroom practices.

What we did was to read the data with the framework in mind and identified relevant data which we organised using the table which had themes as indicated in the framework. How data was presented for interpretation is shown in table 1 which shows the data for theme teacher knowledge and category content knowledge.

Table 1: Data presentation of content knowledge

<table>
<thead>
<tr>
<th>THEME</th>
<th>CATEGORY</th>
<th>CHARACTERISTICS</th>
</tr>
</thead>
</table>
|       | Content knowledge | - (R) Give the order in which you will teach the following and motivate. A. ball is thrown straight upwards and it rises and then drops, B. a ball rolls horizontally on a friction surface, C. a ball is thrown horizontally from the table edge, D. a ball is dropped and E. a ball is thrown at an angle.  
  - (T) No I will start with c and then we will go to b because with c the table is smooth and I can make it a bit rough, ayi sorry its b to c the difference of frictionless and then in c you bring a bit of friction some object will hinder the friction of the ball.  
  - (Incorrect order ~deficiency in the SMK)  
  - (R) How will you answer a student that says….a ball which is rising is accelerating upwards? (T) I will always tell the learner (student) that he must understand it is not accelerating upwards the ball moving upwards it always experience the downwards acceleration (incorrect response, ISMK, M) |
| Teacher knowledge | - (from the picture and thereafter this is what the teacher said) Everything that is thrown upwards come |
down because mother earth has what is called weight.  
[incorrect subject matter knowledge (ISMK), misconceptions (M)]
- the weight of each object is controlled by the weight of mother earth which has a special name (ISMK, M)
- (T) What is the special name of force? (S) It is mass.
- Mass is one of the difficult names in physical science and it is one of the products of weight (ISMK, M)
- Mass is a body and it can go anywhere (subject matter knowledge (ISMK, M)

- There is a relationship between mass and weight but weight cannot be taken as mass because weight has Newton which mass does not have (ISMK, M)
- Which physical quantity has the same unit as Newton? (S) Force. (T) Correct. (ISMK, M)

- (students asked to jump)
- (T)When you jump your height is not the same. What makes it not the same? (S) It is air resistance. Yes it is. (ISMK, M)
- [T] What is free fall? [(group 1) when an object fall and there is no air resistance, (group 2) when object experience gravitational force from the earth and there is no air resistance, (group3) when an object comes down due to gravity. (T) The words which are common are air resistance but you must not say there is no air resistance but that air resistance is ignored because the object comes down due to force of gravity. (ISMK, M)

Prior to the interpretation of data, we completed the diagnostic teacher practice framework.
That is we completed the blocks in the framework with what we identified from the data presented. The completed framework assisted us in interpreting what could be the teaching difficulties which the teacher was not identifying himself but simple conceding to his perceptions. We then interpreted what the data was showing though the framework and gave the findings of what could be the teaching difficulties using the framework.

**Figure 2:** The DTPF after data analysis

Findings using the framework

1. **Teacher knowledge**
   The teacher’s content knowledge was loaded with misconceptions and not organised as shown in table 1. It was also noted that the teacher demonstrated adequate context knowledge because he was aware of what the curriculum entailed in the teaching of projectile motion.
from Grade 10 to 12 as well as the resources available to him at his school for example the laboratory was available even though he it did not have enough chairs but was fairly equipped. Furthermore he acknowledged the challenges offered by the linguistic abilities of his students in the learning of Physical Science. The teacher was also conversant with the prior knowledge students needed to learn projectile motion. Eryilmaz (2002) showed that students learning capabilities depend largely on their prior knowledge and experiences.

The teacher’s knowledge which comprised of content, context and student prior knowledge revealed that it had deficiencies either in the knowledge itself or in the use of the knowledge during teaching. It is interesting to note that in terms of the description of Kaplan and Owings (2001) of teacher quality Mr. Manngo is a quality teacher because he is qualified and brought evidence of a preparation in the classroom. So it cannot be surprising that Mr. Manngo considered himself as such and expected the performance of students to be reciprocal. Wherein it did not he perceived the topic to be difficult to teach.

2. The nature of the language used and meaning making

Though Mr. Manngo was aware of the linguistic challenges his students had he did not do much in the classroom to alleviate or stop the challenge. His language was also loaded with words which showed that the teacher himself also had challenges with the language of teaching. He was observed saying that,

…the weight of each object is controlled by the weight of the mother earth which has a special name and… mass… is one of the difficult names in physical science and it is one of the products of weight…

The talk between the teacher and the students is very important as it facilitates learning and is central to meaning making. Furthermore Mortimer and Scott (2003) indicate that meaning making take place in three phases which are the social plane wherein the teacher provide new content and internalisation wherein the teacher help student make sense of the new knowledge and lastly the application of the new knowledge. So in Mr. Manngo’s case because of the language the atmosphere of new knowledge and internalisation phase was not conducive. The words which the teacher used did not help students comprehend the content as they did not respond correctly to some of his questions for example questions pertaining to weight as well as problem solving.

So some teaching difficulty resulted from the failure to create a situation for the internalisation process to take place because of the language used or words which did not facilitate meaning making by students. In general it can be concluded that the failure of the teacher to use the language that can help students to make meaning even being careful with his words can result in the perception that projectile motion is difficult to teach as the students will fail to make meaning (Mortimer and Scott, 2003) and consequently perform poorly.

3. Prior-knowledge

The teacher knew the prior knowledge students needed to learn projectile motion at grade 12 but its use in the classroom was undesirable. Prior knowledge is important in the learning capabilities of students (Staver, 2006 and Eryilmaz, 2002). Moreover Staver (2006) also indicated that when planning for lessons teachers must take into cognisance the complex interaction between the students’ prior knowledge, their experiences and the new knowledge. Staver (2006) and Eryilmaz (2002) assertions were not evident in Mr. Manngo’s teaching. He did not adequately infuse the students prior knowledge and experiences in his teaching.
However the teacher had acknowledged that students have a problem of not bringing over what they have learnt in the previous grades which hampered the comprehension of the new content. This was evident during the interview when he indicated that,

What I see is that learners tend to have learned horizontal motion in grade 10 &11 and they did not want to link because the only change is the acceleration, they think that the acceleration is due to gravity is a bit different to the horizontal motion whereby they need to know that it is only the acceleration that is constant in the free fall than in the horizontal one

Furthermore Galus (2002) indicated that before teaching projectile motion it is important that students are taught motion for example forces. Mr. Manngo demonstrated that because in the introduction of the lesson he focused on the force. However his explanations were full of misconceptions. This was not surprising as shown before that he had challenges with comprehending forces.

Therefore even though the teacher knew what prior knowledge is required, he did not integrate it such that students make meaningful learning out of it. On the other hand even though he began his lesson with forces, the explanations were loaded with misconceptions which can be transferred to students (Bayraktar, 2009 and Prescott & Mitchelmore, 2005). It can be concluded that some teaching difficulties are as a result of lack of integrating students’ prior knowledge and experiences during the teaching process because it is necessary for the comprehension of the new knowledge (Eryilmaz, 2002) and to avoid memorization (Galus, 2002).

4. Lack of use of resources
In the introduction of the lesson the teacher took out a plastic ball and told students that he always tells them that he does a simple demonstration before teaching. He did a demonstration using an empty packet of chips, a plastic bottle and a piece of chalk. He told students that they must observe what is going to happen to the objects. He held them high and released the bottle first followed by the piece of chalk and asked students what happened to the objects. The second part of the demonstration involved the teacher throwing the plastic bottle and the empty packet of chips upward. The explanations which came from the demonstration did not help students comprehend what the teacher intended to do. This was evident from the lack of responses from students as well as the time taken on discussion on weight.

So the knowledge of the available resources did not help him to conduct a proper demonstration as well as allowing students to conduct the experiment. He claimed that he cannot use the laboratory because there are no chairs. It did not make sense that students had chairs in the classroom which they could have used in the laboratory. This called into question the seriousness of using the laboratory at all. This is the case because when asked why he was teaching students in a room without tables he indicated that, there are no tables because they had to split with the other group which is doing a different subject and the laboratory is not in good condition so they use the classroom for physical science lesson and thereafter students report back to their normal classroom where they are stationed. So the reason for not using the laboratory was not entirely the issue of lack of chairs or its dirtiness. The teacher deliberately avoided using the laboratory.

Therefore it was not the lack of resources that the teacher opted to use the apparatus he used to introduce the lesson but it was a matter of choice. It can also be concluded that some
teaching difficulties resulted from the ignorance of using available resources to enhance the comprehension of the subject matter.

4. Authoritative discourse and the development of inquiry and problem solving skills
The nature of communication between the teacher and the students was largely interactive but authoritative. This means that the teacher did invite responses from the students but if they were incorrect he discarded them, as a result there was a minimal interaction with the students’ responses. For example he asked students to discuss in their groups what free fall is. After some time all the groups had indicated that the object was in free fall because there was no air resistance. The teacher told them they should not say that there is no air resistance rather they must say that air resistance is ignored because the object comes down due to force of gravity. He then said that the group that did the correct thing is the one that said gravity but did not say anything about air resistance. Mr. Manngo then moved to the second question about equations of motion.

According to Staver (2006) learning is an internalised mental process. So the teacher has to provide an atmosphere that will enable the student to internalise new meaning by showing the student where the mistake was made, but the teacher did not do that. Even the kind of questions the teacher asked was to develop the lesson rather than to evaluate where they still lack. Hence it was not surprising that the nature of the discourse was authoritative with a teacher having a fixed intent of rushing to teach equations of motion. Moreover according to Chin (2006) authoritative discourse is made of factual statements and instructional questions which do not leave room for students to think about what the teacher was presenting, which was evident in Mr. Manngo’s interaction with the students in the classroom.

The non-provision of opportunities for students to think cannot help students develop inquiry and problem solving skills (Akarsu, 2010; Akerson & Donnelly, 2010 and Abd-El-Khalick & Akerson, 2009). The DoE (2007) and DBE (2010) also indicated that they examine students on inquiry and problem solving skill in projectile motion so then it is not surprising that students do not perform well. This is so because they are not exposed to the development of those skills in the classroom. As a result the teacher perceive projectile motion as difficult to teach because after teaching them students do not perform as he did not teach them such that they develop the inquiry and problem solving skills. So some teaching difficulties may result from the nature of classroom interactions and discourse.

5. Empiricism and the comprehension of abstract concepts
The teacher used illustrations as his explanatory framework and problems as activities to develop the lesson. According to Magnusson et al. (1999) explanatory frameworks and activities should be used by the teacher to help students to comprehend the subject matter knowledge. However the teacher was focused on providing students with examples so that they learn through experiences without reasoning. Yet the nature of the subject matter is such that it is loaded with abstract concepts (Gunstone et al., 2008 and Schwartz & Lederman, 2008) for example forces, and it demands appropriate explanatory frameworks for students to comprehend such concepts.

It was also noted that during interviews the teacher had indicated the intention to also use experiments in his teaching, of which he indicated that,

If something that involves like in the mechanics part then learners (students) must be taken out of that environment of the class and get outside and investigate some of the things and come back and see if it makes sense
But in practice the teacher used traditional methods of teaching for example demonstrations, lecture and questions and answer methods. According to Schwartz and Lederman (2008) traditional methods of transmitting information which Mr. Manngo used do not help students comprehend such abstract concepts. Even Hollon et al., (1991) indicated that instructional strategies should engage students such that they are able to think which in turn develop problem solving and inquiry skills. Yet the instructional strategies used were so constrained such that they did not offer opportunities to develop problem solving and inquiry skills which is a teaching difficulty. Childs and McNicholl (2007) indicate that the teacher who lacks content knowledge resorts to constrained pedagogy and this was the case for Mr. Manngo. Therefore it can be concluded that the instructional strategies the teacher used did not promote comprehension of the abstract concepts which is a teaching difficulty because according to Kaplan and Owings (2001) instructional strategies are also an important factor in student achievement.

It can also be inferred that the choice of the instructional strategies was influenced by the epistemological perspective (Kuzniak and Rauscher, 2011 and Kalman, 2009) of the teacher which was empiricism. This is so because from the empirical perspective the focus is on learning from experiences (Boeree, 1999) and this was evident in Mr. Manngo’s instructional strategies. Therefore some teaching difficulties result from the teacher’s epistemological perspective.

6. Accountability to the system
During the interviews the teacher indicated that,

I see myself as a physics teacher who has a passion for each and every learner (student) to understand what has transpired in the lesson…when we want to progress the rate we always look at the understanding of the concept because they are going to be questioned by somebody they don’t even know because I have been given a syllabus. One must ensure that at least what we have done if not 100% at least a learner must get 80% of what we have done then the learner can pass at the end of the year because we cannot get 100% all the time but if you get 80 or 70% of what we have learned you have done justice for that and then we complete the syllabus

So the teacher had intentions to help students understand the content as well as complete the syllabus, but in practice the focus was more on completing the syllabus. The teacher rushed through the lesson and even though he had planned an experiment to be done prior to the teaching of the equations of motion, it was not done. He did not infuse their prior knowledge as well as using their own languages in the explanations of some concepts for example the weight. If that was done it would help with the internalisation phase (Mortimer and Scott, 2003) and improve meaning making which in turn influence performance.

The past results of the school and the external pressure from the district and provincial office could have left the teacher rushing through the content without taking into cognisance if students comprehended the content or not. Even though extra time was taken by the teacher to complete the syllabus the focus was not on giving students more time to comprehend the content but to finish the syllabus. Therefore the teacher was accounting to the system (Jita, 2004). So even though the teacher had indicated that he accounts to all stakeholders, it was not evident in his practice. Therefore it can be concluded that some teaching difficulties are as a result of the accountability focus of the teacher in the classroom.

Conclusion
It was the purpose of this study show that the DTPF can be used to analyse the classroom practices of a teacher and to determine the teaching difficulties. We are of the view that this paper showed that the framework can be used for that purpose. The way the framework was used and how it assisted us to determine teaching difficulties should add into the debate on teacher practices in science teaching on what are the areas to focus on and how that can be done. We also envisage that the hands-on practicing members of the teaching community which are the science teachers, head of departments, deputy principals and subject advisors and other service providers can use this framework as a fundamental resource to identify the teacher’s areas of development in his practices. We also envisage that researcher can also use the framework as it was done in this study to derive a picture of how different aspects generate the teaching difficulty. The study also showed that it can be possible to provide tailored intervention either be content knowledge, context knowledge, instructional strategies or nature of discourse as the deficiency will have been outlined in the DTPF. We also concede that this has not been tested at a large scale and it will be an interesting area for further research.

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Exploring high school teachers’ conceptions of the nature of scientific inquiry: A Case study

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The paper explores conceptions of the nature of scientific inquiry (NOSI) for five teachers who were purposively and conveniently sampled from five schools in Gauteng, Johannesburg. Teachers’ conceptions of the NOSI were determined using a Probes’ questionnaire. To confirm each teacher’s responses, a semi-structured interview was conducted for each teacher. The Probes questionnaire was based on six tenets of the nature of scientific inquiry. However, results from only three tenets namely: (1) scientists use a variety of methods to conduct scientific investigations; (2) scientific knowledge is socially and culturally embedded; and (3) scientific knowledge is partly the product of human creativity and imagination are reported in this paper. The study found that the teachers hold mixed NOSI conceptions which are fluid and lacked coherence ranging from static, empiricist-aligned to dynamic, constructivist-oriented. Although all participants expressed some views that were consistent with current acceptable conceptions of NOSI, some held inadequate (naive) views of the NOSI on the crucial three NOSI aspects. The study recommends that the NOSI should be taught explicitly during pre-service and in-service training so as to enable teachers to possess informed conceptions about the NOSI. With informed conceptions of the NOSI, teachers can craft pedagogies which are appropriate for involvement of learners in both scientific inquiry and understanding of the NOSI.

Introduction

During the last three decades, the science education community has established a research agenda calling for more studies focused on teachers’ conceptions of the NOSI (Crawford, 2000; Keys & Bryan, 2001; Schwartz, Lederman, & Lederman, 2008; Windschitl, 2002). Recent research (Bartels, Lederman, & Lederman, 2012; Hacıeminoğlu, Yılmaz-Tüzün, & Ertepınar, 2012; McNeill, Lizotte, & Krajcik, 2005; Sampson & Grooms, 2008; Schwartz, Lederman, & Abd-El-Khalick, 2012) and reform documents (American Association for the Advancement of Science, 1993; National Research Council, 1996) advocates critical roles for teachers in structuring and guiding learners’ conceptions of the NOSI; a major learning goal in science education reform efforts. According to Grandy and Duschl (2007) advocacy for scientific inquiry, which has resurfaced during the last ten years or so, is to be found in both current science education research agendas and in contemporary school science curricula reform documents. Research efforts in this regard have often conflated or combined the nature of science (NOS) and nature of scientific inquiry (NOSI) conceptions under “students’ or teachers’ understandings of science” (Schwartz, et al., 2008, p. 3). Conflation refers to the two constructs being combined into one whole under a more general term, for example, ‘understanding of science’ meaning the two constructs are taken to refer to the same thing. To avoid confusion, it is important to make a clear distinction between NOS and NOSI. The term “nature of science” is reserved to refer to an individual’s views, ideas, beliefs, assumptions and values about scientific knowledge only (Schwartz, et al., 2012; Schwartz, et al., 2008). The NOS refers to descriptions of the products of science. By the products of science, it is meant the facts, theories, principles, models, etc. making the body of knowledge called science. To Schwartz (2007), nature of scientific inquiry refers to the processes and
elements therein of scientific investigations and methods of justifying knowledge. Conceptions of the nature of scientific inquiry are an individual’s ideas, beliefs, assumptions and understanding about the scientific process, what scientists do and how scientific knowledge is developed and validated (Schwartz, Lederman, & Crawford, 2004; Vhurumuku & Mokeleche, 2009). Conceptions of the nature of scientific inquiry are not the abilities or skills to perform (to do) scientific investigations, but rather the beliefs, views, perceptions and assumptions attached to the activities by the individual. One focal point as a result of this conflation has been the conceptions of NOS and scientific inquiry (Bell, Maeng, Peters, & Sterling, 2010; Schwartz, et al., 2008). In view of the fact that NOS aspects are those that pertain to the product of inquiry, the scientific knowledge and NOSI aspects are those that pertain most to the processes of inquiry, the “how” the knowledge is generated and accepted, the study reported here focuses on NOSI and not NOS and this becomes the point of departure of this study from previous studies on NOS. Processes of inquiry refer to activities such as asking or framing research questions, designing investigations, experimenting, observing, concluding and inferring. This study is the first to specifically look at teachers’ conceptions from a NOSI lens. This is especially important because the literature is replete with instances where descriptions of the two constructs, NOS and NOSI are indistinct, overlapping and consequently confusing (see, for example, Bell, et al., 2010; Lederman & Lederman, 2005; Schwartz, et al., 2012; Schwartz, et al., 2008). This distinction charters the line of research pursued in this study as a foray into relatively virgin land.

While some studies focusing on teachers’ conceptions of the NOSI have been done (see, Abd-El-Khalick, 2002; Campbell, Abd-Hamid, & Chapman, 2010; Kang & Wallace, 2005; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Lederman, Wade, & Bell, 1998; Linneman, Lynch, Kurup, Webb, & Bantwini, 2003; Sutherland & Dennick, 2002; Zeidler, Walker, Ackett, & Simmons, 2002), the results of these studies have been contradicting. The results of some studies have shown that many teachers harbour naive and inadequate understandings of both NOS and NOSI (e.g., Abd-El-Khalick, 2002; Campbell, et al., 2010; Kang & Wallace, 2005; Lederman, et al., 2002; Lederman, et al., 1998; Linneman, et al., 2003; Sutherland & Dennick, 2002; Zeidler, et al., 2002), while other studies show that some teachers harbour informed views (e.g., Abd-El-Khalick, 2002, 2006; Abd-El-Khalick, Randy, & Lederman, 1998). Results of studies which has shown that teachers harbour naive views give an overall picture that the majority of science teachers view scientific knowledge as immutable truth, possess absolutist viewpoints, have little, if any, formal exposure to NOS and/or NOSI. If science knowledge and understanding are expected to be broader than the concepts of physics, chemistry and biology; and if the processes of science are to be taken seriously as a reference for teaching styles and strategies, then the NOSI needs to be addressed. The present study is undertaken in the South African context and, in the first instance, consequently represents an attempt to explore Grade 11 teachers’ conceptions of the NOSI. Secondly, the study seeks to promote further debate among African science educators for the need to possess informed NOSI views consistent with the main thrust of the science reform agenda (see, American Association for the Advancement of Science, 1993; Anderson, 2002; Grandy & Duschl, 2007; National Research Council, 1996). For science educators, the rise of science, the conduct of science, its influence on values and priorities, and its relation to social responsibility are difficult to discuss without reference to some understanding of the NOSI itself. Given that teachers do not teach what they do not know (Bady, 1979; Keys & Bryan, 2001), what conceptions are teachers passing on to learners about the nature of scientific inquiry? A question is asked; Do South African teachers’ hold valid conceptions of the NOSI? Because little is known about how teachers conceptualize inquiry, how these conceptions are formed and reinforced (Windschitl, 2004), this study addresses this omission
by focusing on South African secondary schools teachers’ nature of scientific inquiry conceptions.

**Purpose of the study**
The study sought to explore Grade 11 teachers’ conceptions of the nature of scientific inquiry. In order to achieve the purpose of this study, one major research questions was formulated:

*What are teachers’ conceptions of the nature of scientific inquiry?*

**Theoretical Framework**
This study is guided by the literature on operationalization and categorization of the phrase *conceptions of the nature of scientific inquiry* (Deng, Chen, Tsai, & Chai, 2011; Schwartz, 2007; Schwartz, et al., 2008). Scientific inquiry refers to the methods and activities that lead to the development of scientific knowledge (Schwartz, et al., 2004). Within a classroom, scientific inquiry involves learner-centred projects, with learners actively engaged in inquiry processes and meaning construction, with teacher guidance, to achieve meaningful understanding of scientifically accepted ideas targeted by the curriculum (Krajcik, Blumenfeld, Marx, & Soloway, 1994; Minstrell & van Zee, 2000; National Research Council, 1996; Roth, 2008). This entails using a variety of activities to develop learners’ knowledge and understandings of both scientific ideas and how scientists study the natural world. In this study, conceptions of nature of scientific inquiry are taken to include an individual’s ideas about the scientific process and enterprise. What constitutes conceptions of NOSI are not the abilities or skills to perform (to do) investigations, but rather the beliefs, views, perceptions and assumptions attached to the activities by the individual. Teachers’ conceptions of nature of scientific inquiry were established using three tenets which are: (1) scientists use a variety of methods to conduct scientific investigations; (2) scientific knowledge is socially and culturally embedded; and (3) scientific knowledge is partly the product of human creativity and imagination. 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. These tenets are captured in the Probes instrument.

Deng, et al., (2011) categorised conceptions of nature of scientific inquiry (NOSI views) as existing along a continuum ranging from static, empiricist-aligned views, through fairly constructivist views to dynamic, constructivist-oriented views. The static, empiricist-aligned views of science subscribe to such notions as: scientific observations and interpretations are objective and theory free, science is culture free, there is one method of science, scientific knowledge is sourced from observation and experiment only, scientific theories develop into laws, scientists are humans with extra-ordinary intelligence and that science is entirely empirically based knowledge. To Alchlin (2001) and Clough (2007), these notions seem to be myths about nature of science and NOSI. However, according to Deng et al.’s categorisation; these are taken as naive views about the nature of scientific inquiry. On the extreme pole of the continuum are desirable, contemporary, and highly adequate and largely dynamic, constructivist-oriented views who subscribe to notions as: scientific observations are subjective and theory-laden, scientific knowledge is a product of human creativity, imagination and serendipity, there is no one method of science, science is not culture free, and that science is just another humane enterprise. Literature of on NOS and NOSI (Abd-El-Khalick, 2006; Allchin, 2001; Clough, 2007; Deng, et al., 2011; Schwartz & Lederman, 2008), take these notions as informed conceptions about the NOS and NOSI. This lens which
is constructivist-oriented was adopted by this study for analyzing teachers’ conceptions of the NOSI. Each of the teacher’s conceptions on the three tenets was considered, and an overall decision made about the adequate or inadequate nature of a teacher’s conceptions. This consideration resulted in placement of the teachers along a normative map ranging from poorly inadequate through inadequate (naive), moderately adequate (transitional), highly adequate to extremely adequate (informed). Such a nomothetic categorization of the teachers’ views was considered necessary for it aided the triangulation of the nomothetic placement of teachers done using the Probes questionnaire instrument.

However, the NOSI remains a difficult and problematic construct to deal with and presents many challenges for the teacher and teacher educator (Ryan & Aikenhead, 1992). For instance, various schools of thought ascribe plural meaning to the same NOSI aspect. Conceptions of the NOSI are thus pluralistic. Five major schools of thought, as recognised by Western philosophers, serve to illustrate how this pluralism arises. Realism, Falsificationism, Conventionalism, Objectivism and Research methodologist provide useful philosophical groupings in which teachers’ conceptions of the NOSI can be categorised. Eflin, Glenman, & Reisch (1999) however hint that these philosophical perspectives are not alternatives to each other. The extent to which these schools of thought are prioritised by an individual teacher in expressing his or her views of the NOSI depends on the cultural and historical context (Lederman, 1992; McComas, 1996). Its interpretation in African settings presents a further set of challenges (Jegede, 1989, Ogunniyi et al., 1995). Beliefs and values, particularly when strongly held introduce a worldview context that is likely to have its own influence on the interpretation of the NOSI (Cobern, 1993, 1996). For purposes of this study, the five schools of thought are defined generally as follows:

**Realism**: there exists an objective truth about nature that is independent of one’s thinking. The realist ontology postulates theoretical constructs about existence of entities that cannot be seen e.g. genes, electrons, black holes (Dawson, 1991). It goes on to say that scientific knowledge is ideal knowledge because it is based entirely on observation.

**Falsificationism**: suggests that science proceeds in the opposite direction, beginning with scientific theories or “conjectures”, and then conducting experiments and eliminating those theories that are falsified by results. This scientific philosophy is based on the premise that a hypothesis must be falsifiable to be scientific; if a claim is not to be refuted then it is not a scientific claim.

**Conventionalism**: theory and truth are not fixed by nature but are creations of the mind. Thus, choice between rival theories is never determined by the facts and logic alone.

**Objectivism**: allows a person to achieve reality-oriented thought. Thinking, to be valid, must adhere to reality. It is the belief that certain things exist independently of human knowledge or perception of them.

**Research methodologist**: Always thinks of using multiple methods, each as applied to various facets of the whole scope of the methodology to solve a scientific investigation.

**Research Methodology**

**Sampling**

The participants were five experienced Grade 11 Physical Science teachers purposefully and conveniently chosen (Patton, 1990) from five Metropolitan High schools in central Johannesburg, in the Gauteng Province of South Africa. The five teachers, pseudo-named, Ranelo, Hedwick, Jairos, Johnny and Booi were chosen for this study for two major reasons. First, from a possibility of ten schools that place emphasis on Mathematics, Science and Technology, they are the ones who were adjudged to be the most experienced and also
appeared to be cooperative and willing to participate in the study. Their experience in teaching Physical Science ranged from 15 to 22 years. Secondly, all five teachers were qualified to teach Physical Science and had a minimum of a Bachelors’ degree in Science including the education component. Four of the teachers (Hedwick, Jairos, Booi and Ranelo) were studying towards a Master of Science degree. All teachers were teaching Physical Science at Further Education and Training (FET) level.

**Instruments**

**Probes**

To investigate the five teachers’ NOSI conceptions, a Probes’ questionnaire was administered. Probes were chosen for this study because it was felt that they provide contexts for respondents to reflect on their NOSI conceptions (Jääskö & Mattelmäki, 2003). The probes were adapted from three instruments namely the VOSTS (Aikenhead & Ryan, 1992), the VNOS-Form A (Lederman & O’Malley, 1990) and VNOS- Form C (Lederman & Abd-El-Khalick, 2002). Essentially, the written instrument consists of 6 probes related six NOSI aspects. One probe was used for each of the six NOSI tenets that belong to the NOSI. For this paper, only three NOSI aspects (scientists use a variety of methods to conduct scientific investigations; scientific knowledge is socially and culturally embedded; and scientific knowledge is partly the product of human creativity and imagination) are presented and analysed. All probes in the questionnaire have a common style and are based on the same context. Each probe presents a scenario followed by a number of different options, which are presented in the form of conversations. The respondents are requested to select only one of the alternatives provided, which is deemed to be most appropriate. They are also asked to provide a detailed justification for their choice. The explanations for their decisions provide insight in the underlying reasoning on which their actions are built. By providing the option “I have a different idea” or “I have another view which I will explain” for all probes, respondents are encouraged to formulate alternative choices (with rationale) on the issue discussed in the probe. Each probe had to be answered in no strict sequence. This questionnaire was administered before teacher interviews were conducted. Each teacher took between 20 and 30 minutes to complete the instrument.

![Figure1: An Example of a NOSI item](image)
Review of pertinent literature shows that previous studies (see, for example Ibrahim, Buffler, & Lubben, 2009; Lederman, 2008) carried out with similar target groups showed that the use of real-life figures and names can lead to prejudice towards the selection of an option. Consequently, to improve construct validity of the responses, cartoons were used and labelled by letters to present the various options for each question, as they do not refer to any aspect of gender, race and culture. The vocabulary was chosen to be simple and the words were reduced to a minimum. Respondents were asked to complete the set of written probes individually and in no strict sequence. The content validity for each of the probes was improved by peer reviews from university professors (six from science disciplines) and twenty-five (25) postgraduate science (physics, chemistry and biology) students.

**Semi-Structured Interviews**

Teachers were interviewed for the purposes of confirming responses from the Probes instrument and getting a deeper understanding of teachers’ NOSI conceptions. Each teacher was asked a set of core questions around which probing for clarification and deeper understanding was done. Further probing and prompting was done depending on the responses given by the interviewee. The structuring of the core questions was informed by the literature (Kirschner, Sweller, & Clark, 2006; Liang, et al., 2006; Ryder & Leach, 2000; Saunders, Cavallo, & Abraham, 1999). The semi-structured interviewing was done around the following questions:

What can you say about the methods scientists use in their investigations or experiment? Is scientific knowledge culture free? Explain.

From what you do with your learners during Chemistry practical investigations, what can you say about the use of imagination and creativity in science?

Do you think what you do in the Chemistry practical investigation with your learners is similar to what is done in scientific laboratories?

Why do scientists do experiments?

Where do you think scientific knowledge comes from?

How do scientists build scientific knowledge?

**Data Analysis**

**Probes**

Coding of learners’ responses was based on the choice of action (A, B, C) together with the explanation for their actions. Categories of responses to individual probes were developed using a hybrid model produced after fusing the Ibrahim, Buffler and Lubben’s (2009) model for coding probes with that of Liang et al.’s (2009) rubric for scoring SUSSI open-ended responses. Criterion validity of the analysis was improved by employing a coding system independently generated for each of the probes by two researchers (the researcher and a post-doctoral research fellow registered at the same university). To analyze data from Probes’ open-ended responses, the researcher read through sets of transcripts making preliminary notes regarding patterns that emerged from individual participants. This followed a model used by Ibrahim, et al. (2009) and Campbell, Lubben, Buffler and Allie (2005) since the structure of the probes used were similar. However, the coding was not exactly the same as done by Campbell, Lubben, Buffler and Allie in their monograph on teaching scientific measurement at the University of Cape Town. Thus, some aspects of grounded theory analytical procedures (Strauss & Corbin, 1998) especially interpretive analysis (see, e.g., Gall, Gall, & Borg, 2003) were used to inductively analyze the participants’ probes’ open-ended responses. The data collected from the sets of open-ended probes’ responses were coded using the hybrid model. These procedures involved (1) the simultaneous collection and analysis of probes data and (2) comparative methods of analysis whereby participants’
responses were compared among one another and within each participant, and (3) the integration of a theoretical framework.

The transcribed probes data were read looking for patterns, relationships and other themes within the responses. Entries were coded according to patterning identified while keeping a record of what entries went with which element of the patterns. In other words, the data was read and then chunked based on common language. Underlying reasoning was then identified for each teacher by writing the category codes for each probe response and this enabled conceptions of the nature of scientific inquiry to be determined for each teacher’s response.
Semi-Structured Interviews

Analysis of transcripts from teacher interviews was done using a ‘‘hybridization’’ of the processes of analytic induction, sequential analysis and interpretational analysis following the procedure used by Vhurumuku, Holtman, Mikalsen, & Kolsto (2006). For each teacher, transcribed teacher interview notes were entered into ATLAS.ti version 6.2 and analysed as data sets. The analytic induction involved continued reading and re-reading of transcriptions to unveil common patterns. For each data set, emerging patterns were then used to develop categories, which were categorised around philosophical groupings. Responses were then classified on the basis of the formed categories. The data were also looked at from the angle of sequential analysis, a slight variation to analytic induction (Harwell, 2000). In this process, interpretations for each response to a question were written as memos and comments. Memos and comments are methods used to record one’s ideas and observations about codes, quotations and the hermeneutic unit (HU). Formed comments and memos were reduced to clusters based on the responses. Cluster phrases emerged from the responses. For each of the processes, that is, analytic induction and sequential analysis, each researcher independently did the analysis. This was followed by a process of discussion, negotiation and adjustment leading to consensual arrival at common assertions and clusters. Interpretational analysis involved getting meaning out of the data. As a researcher, I asked the following question: What does this mean? Meaning was found by categorising teachers’ responses into philosophical groupings the responses fitted.

Results

As Table 1 below shows, the teachers generally held both highly adequate and extremely adequate views (informed views) of the nature of scientific inquiry considering the closed section of the probes instrument. Four of the five teachers agreed on the three aspects of the NOSI whilst one teacher disagreed with the rest. Only one teacher seemed to contradict himself by believing that scientists use the scientific method to perform various investigations (probe 1) and at the same time by believing that science is a blend of logic and imagination (probe 3).

Table 1: Summary of Probes Closed-ended responses (n = 5).

<table>
<thead>
<tr>
<th>Probe</th>
<th>Choice</th>
<th>Description</th>
<th>No. Of Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>Scientists use one method to conduct investigations</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>No, scientists use a variety of methods to conduct investigations</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>I have another view which I will explain</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>Scientific knowledge is socially and culturally embedded</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>No, scientific knowledge is not socially and culturally embedded</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>I have another view which I will explain</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>Scientists use human creativity and imagination to create scientific knowledge</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>No, scientists do not use human creativity and imagination to produce scientific knowledge</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>I have another view which I will explain</td>
<td>1</td>
</tr>
</tbody>
</table>

*Scientists use a variety of methods to conduct scientific investigations*
Four of the five teachers (Hedwick, Jairos, Ranelo and Booi) believed that scientists use a variety of methods to conduct scientific investigations. When responding to the probe related to this aspect, they wrote:

PMSCIT1 (Ranelo): A variety of methods are used. The procedure of an experiment depends on a question to be addressed. However, the scientific method must be used to check the conclusions.

PMSCIT2 (Hedwick): There are so many methods of doing investigations. Some discoveries are made by accident (e.g. penicillin). I understand the structure of benzene was discovered based on a dream.

PMSCIT3 (Jairos): There are several ways of conducting scientific investigations, e.g. speculation, experimentation, library investigations etc.

PMSCIT5 (Booi): Scientists use a variety of methods during investigations to arrive at the same conclusions.

These responses show highly adequate (informed) views. Based on their responses, the four teachers can be classified as research methodologists. However, of interest is Ranelo’s response who believed other methods can be used to conduct investigations but components of the scientific method should be used to confirm the results. During interviewing Hedwick, Jairos and Booi maintained their position by giving more or less the same responses they had given in the probes questionnaire. Ranelo qualified his probe response too when asked the question “what can you say about the methods scientists use in their investigations or experiments?” He said:

Tr1Int (Ranelo): Scientists employ a variety of methods but for confirmation of results, scientists have to use an orderly step-wise procedure. Then they can be sure of their results after having followed a logical common method.

This response shows that Ranelo is also a conformist/ verificationist and objectivist. He believed other methods can be used to conduct investigations but components of the scientific method should be used to confirm the results. Johnny did not think that way. His probe response was:

PMSCIT4 (Johnny): Scientists use one method of logical steps known as the scientific method to perform various investigations.

This view is categorized here as poorly inadequate (naive). The view was cross-checked and validated during interviewing and Johnny qualified his conception by further saying:

Tr4Int (Johnny): Scientists need to prove each other incorrect in scientific arguments. For them to be able to do this the same method of scientific investigation should be used and there is only one method known for accuracy called the scientific method. I use this method with my learners as from Grade 10[...]

This response fits into Rudolph’s (2005) description of the scientific method when he lamented that the more nuanced step-based accounts of scientific processes, when formalized for school curricula, risk getting altered and distorted into rigid steps. The idea that science is a linear process often portrayed in the science classroom by the scientific method is also raised by the majority of the teachers (85%) in a study by Abd-El-Khalick (2006). Johnny is classified as a falsificationist and objective. In reality, there is no single universal step-by-step scientific method that all scientists follow. Several methods are employed.

*Scientific knowledge is socially and culturally embedded*
Four of the five teachers held contemporary and informed views that science is part of social and cultural traditions. Scientific ideas are affected by their social and cultural milieu. Hedwick, Jairos, Johnny and Booi were of the opinion that scientific knowledge is not social and culture free. When responding to the probes item regarding this aspect, the four wrote:

PNSKT2 (Hedwick): Science as a phenomenon is not conducted in a vacuum. Society and culture do influence research; for example, war-mongering cultures and nations like the United States of America invest and conduct research into weapons and so forth.

PNSKT3 (Jairos): Science is everywhere and as such scientific ideas are affected by their cultural, social and political settings.

PNSKT4 (Johnny): Everything in science is part of life so social issues affect science directly; in reality science aims to resolve societal and cultural problems.

PNSKT5 (Booi): Scientists’ knowledge comes from what they believe in, i.e. their social and cultural locale; social issues affect science in a way that scientists find a need in their social life and try to fix that problem using science.

These responses are confirmed by the teachers’ responses to the interview question, “Where do you think scientific knowledge comes from?” Jairos explained:

Tr3Int (Jairos): Science as a human endeavour is influenced by the society and culture in which it is practised. On one hand, in school science for example, politicians will always influence the design and contents of the science syllabus. They will also influence education, particularly science education. Society holds a particular idea like a science phenomena, for example, lightning. You find that some societies believe that lightning can be created by an individual to fight against one another. Social problems on the other hand determine the research to be pursued to solve those nagging societal problems, for example, nowadays there is so much expanded research on HIV and AIDS, global warming and the use of genetic engineering. Booi concurred:

Tr5Int (Booi): As much as scientific knowledge aims to be universal and general, science is affected by social and cultural beliefs because science reacts to societal and cultural problems. Cultural values determine what science is conducted and accepted. Issues like the HIV and AIDS pandemic, use of non-renewable energy sources and famines has resulted in so much money being channelled into the research of HIV and AIDS, global warming and genetic engineering by politicians.

While these responses show quite sophisticated views of this NOSI aspect, Ranelo did not think that way. He thought science is a search for universal truth and fact which is not affected by culture and society. When completing the probe item in regard to the nature of scientific knowledge, Ranelo wrote:

PNSKT1 (Ranelo): Scientific knowledge is not influenced by society and culture, but on facts. For example, lightning has the same effect no matter how it is produced and which culture one belongs to.

Ranelo’s view can be described as “realism”. His view is based on the idea that there exists an objective truth about nature that is independent of one’s social and cultural affiliation. This view is categorized here as inadequate (naive). During interviewing, this is what he said:

Tr1Int (Ranelo): Science is based on facts. Most of the time science proves social and cultural beliefs held by individuals wrong. In the olden times people believed that the sun moved around the earth but Science proved that it was the earth that moved around the sun even though the church was against that fact. Another example is that of lightning which has the same effect no matter how individuals believe it is produced. To me scientific knowledge is not socially and culturally embedded.
Though Ranelo’s argument is reminiscent of the argument peddled with much emotion by Copernicus and the Christian religion, according to Inokoba (2010), science as an endeavour and phenomenon is not conceived and operated in a cultural and environmental vacuity. It is a social phenomenon greatly influenced by the prevailing cultural traits and worldview of a people such as their social values, priorities, ideas, skills ethics, perception of social reality and belief systems. Cultural values and expectations determine what and how science is conducted, interpreted and accepted. The history of science is replete with other examples on the social and cultural influence of science including that of Darwin and Galileo.

**Scientific knowledge is partly the product of human creativity and imagination**

The five teachers’ views fall into two categories regarding this NOSI aspect. There is Hedwick, Jairos, Johnny and Booi whose views were conventionalist and totally believed that scientific knowledge and truth are not fixed by nature but are also creations of the mind. In responding to the corresponding probe item, they wrote:

PCSKT2 (Hedwick): Dalton used imagination when interpreting data to say matter is made up of atoms so scientists do use imagination and creativity when creating new knowledge.

PCSKT3 (Jairos): One has to be highly creative and imaginative to further pursue general views so imagination and creativity are used a lot by scientists in creating new knowledge.

PCSKT4 (Johnny): Scientists are the most creative and imaginative beings on this planet because it is of these two; imagination and creativity that they use very well and new knowledge is born.

PCSKT5 (Booi): By coupling imagination and creativity with experience and experiments scientists create new knowledge.

These views are categorized here as highly adequate (informed). Through further probing and prompting, interesting responses were given by the teachers to solidify their views and position. This is what Jairos said:

Interviewer: Do you think scientists use imagination and creativity when they do their work?

Tr3Int (Jairos): For anybody to come up with something recognizable or of academic stamina, one has to imagine things. When one has an idea, he has to be creative or have the notion, for example, let us talk about Boyle’s apparatus, for him to come up with a U-tube and all those things he had to imagine things. He had to be very creative. The idea of trying to measure pressure was there. That was the idea, how can I measure pressure? Right....aah! Then he used his imagination and creativity to come up with what we call today-the Boyle’s apparatus.

Interviewer: In your teaching of investigations how do you make sure these two constructs are infused?

Tr3Int (Jairos): It is a point of saying to the learners we know most of the time the expected or desired result but if it does deviate from the norm, that is, if you do get observations that are out of expectation do not be afraid to record what you have established because that is how science functions. There are no set of rules that if you actually follow the following steps you will actually end up at a particular result. For sure science does not operate like that.

Then there is Ranelo who did not think that way. Ranelo did not think that scientific knowledge was a product of imagination and creativity because both human creativity and imagination are in conflict with scientists’ objectivity. This view can be described as “realism”. Ranelo appears to base his thinking on the belief that there exists an objective truth about nature that is independent of one’s thinking. This makes Ranelo a realist. When completing the probes instrument, Ranelo wrote:
PCSKT1 (Ranelo): Scientists do not use imagination and creativity when creating new knowledge because the two interfere with objectivity and I do not use creativity and imagination at all as an individual. During interviewing, when asked, “From what you do during Chemistry practical investigations, what can you say about the use of imagination and creativity in science?” Ranelo said:

Tr1Int (Ranelo): Scientists don’t use imagination or creativity because they won’t be able to prove what they have come up with. I do the same, I do not use it and I encourage my learners not to use it because it interferes with objectivity. Science is all about proving facts. This response shows quite naive views of the NOSI. Ranelo’s meaning of the term objective here appears to be the same as that for the term real. To Ranelo, if an idea cannot be proven then it is not scientific and not real. Ranelo has to be reminded that scientists do not solely rely on logic and rationality. In fact, creativity so is imagination are a major source of inspiration and innovation in science and it permeates the ways scientists design their investigations, how they choose the appropriate tools and models to gather data and how they analyze and interpret results. Considering the responses given by the five teachers to the probes instrument items and interview probes, a summary of teachers’ views on the selected NOSI aspects was constructed. This is presented as Table 2.

Table 2: Summary of teachers’ conceptions on three selected NOSI issues

<table>
<thead>
<tr>
<th>Teacher</th>
<th>NOSI views</th>
<th>Use of Imagination and creativity when conducting investigations</th>
<th>Methods scientists use to conduct investigations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranelo</td>
<td>Realist/Inductivist- science is a search for universal truth and fact which is not affected by culture and society</td>
<td>Realist- if an idea cannot be proven then it is not scientific and not real.</td>
<td>Objectivist/verificationist- other methods can be used to conduct investigations but components of the scientific method should be used to confirm the results.</td>
</tr>
<tr>
<td>Hedwick</td>
<td>scientific knowledge is not social and culture free</td>
<td>Conventionalist-believed that scientific knowledge and truth are not fixed by nature but are also creations of the mind</td>
<td>Research methodologist-multiple methods, are used through various facets of the whole investigative process when solving a problem</td>
</tr>
<tr>
<td>Jairos</td>
<td>scientific knowledge is not social and culture free</td>
<td>Conventionalist-believed that scientific knowledge and truth are not fixed by nature but are also creations of the mind</td>
<td>Research methodologist-multiple methods, are used through various facets of the whole investigative process when solving a problem</td>
</tr>
<tr>
<td>Johnny</td>
<td>scientific knowledge is not social and culture free</td>
<td>Conventionalist-believed that scientific knowledge and truth are not fixed by nature but are also creations of the mind</td>
<td>Falsificationist/ Objectivist-there is a single universal step-by-step scientific method that all scientists follow</td>
</tr>
<tr>
<td>Booi</td>
<td>scientific knowledge is not social and culture free</td>
<td>Conventionalist-believed that scientific knowledge and truth are not fixed by nature but are also creations of the mind</td>
<td>Research methodologist-multiple methods, are used through various facets of the whole investigative process when solving a problem</td>
</tr>
</tbody>
</table>

Discussion
One of the most widely held inadequate or naive ideas about science - the existence of a universal, step-wise “Scientific Method” was confirmed by this study. Interestingly, only one teacher (Johnny) harboured this view. The other teacher (Ranelo) believed scientists can use all other methods they can come up with but at the end, the steps of the “Scientific Method” should be used to verify and confirm results. The National Science Education Standards (National Research Council, 1996) and Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993) have for long debunked this notion. There is no such method (Bauer, 1994). Such naive patterns are highly unlikely to be attributed to chance but it is most likely that these teachers have been explicitly exposed to these naive ideas about the scientific knowledge, for example, through introspection of Ranelo’s argument. According to McComas and Olson (1998) people believe in the existence of the scientific method because of the way scientific research has been propagated and reported in journals and books. In many instances, the reports are presented in the same format as the so-called scientific method (see, Emiliani, Knight, & Handweker, 1989; Hewitt, 1998; Hill & Petrucci, 1996). From the formats of these reports people have made erroneous conclusions that this is how science works. While scientists might do some of the activities listed in the so-called scientific method, in practice they do not go step-by-step through the steps. What happens in reality is scientists approach and solve problems in different ways. Serendipity and dream can also be used as mentioned by Hedwick in her probes’ responses. Four of the five teachers believed science is not a social and cultural free endeavour. This is an informed view. They saw scientific knowledge being subjective to a certain degree. They gave such factors as the existing scientific knowledge, social and cultural contexts, the researcher’s experiences and expectations influencing how data is collected and analyzed and conclusions drawn from these data. These results are however inconsistent with results from a study conducted on Turkish teachers by Macarolu, Taşar, & Cataloglu (1998). In particular, the researchers found that their participants believed that scientific knowledge was objective, that is, it lacked the social and cultural embeddedness. This is the same view held by Ranelo which is naive. As a human endeavour science is influenced by the society and culture in which it is practised. Topical issues like HIV and AIDS, global warming and genetic engineering are getting well researched because of their impact to different societies and cultures. Liang et al. (2008) sum it all by saying “cultural values and expectations determine what and how science is conducted, interpreted and accepted” (p. 992).

Intricately linked to the subjectivity of science is the use of imagination and creativity in scientific investigations. Ranelo argued that if imagination and creativity were to be used in science, then science loses it worth of being a body of facts. To Ranelo, science is proven truth and scientists have to prove each other wrong if they do not agree with each other. Through use of imagination and creativity, this would not be possible. What a naive and realist argument put forth by Ranelo. As a word of caution, Bell, Maeng, Peters, & Sterling (2010) hint “scientists do not solely rely on logic and rationality” (p.11). Because science is a blend of logic and imagination, creativity becomes a major source of inspiration and innovation in science. Similar and consistent findings have been found in other studies (see, e.g., Abd-El-Khalick, 2006; Bell, Blair, Crawford, & Lederman, 2003; Mackay, 1971). Scientists have to think and be creative like an artist would create an artifact out of wood or stone or a musician compose music or a poet write poetry when inventing hypothesis or theories to imagine how the world works.

Conclusion
The five teachers’ NOSI conceptions on the three NOSI tenets were found to be fluid and lacked coherence. Although all participants expressed some views that were consistent with
current acceptable conceptions of NOSI, some held inadequate (naive) views of crucial NOSI aspects on all three NOSI aspects: the existence of a universal, step-wise “Scientific Method”, scientific knowledge being socially and culturally embedded and scientific knowledge being partly the product of human creativity and imagination. Given that teachers do not teach what they do not know (Bady, 1979; Keys & Bryan, 2001), it can be argued from the results of this study that teachers are passing on mixed NOSI conceptions, both naive and informed to their learners. It is recommended that the nature of scientific inquiry be taught explicitly during pre-service and in-service training so as to enable teachers to possess informed conceptions about the NOSI. With informed conceptions of the NOSI, teachers can craft pedagogies which are appropriate for involvement of learners in both scientific inquiry and understanding of the NOSI.

References


Teaching Thinking, Study, Investigative and Problem Solving Skills in Biology: A case of curriculum implementation in Zomba schools

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Abstract
This paper reports on a study of how new content free topics in Junior Secondary Biology were perceived by teachers as way of exploring the implemented curriculum. The topics were study, thinking, investigative and problem solving skills. It was hypothesized that there would be a mismatch between what the curriculum developers and textbook writers desired and how teachers taught them, since teachers had no experience in them. Questionnaires were administered to 32 teachers from randomly selected schools in Zomba, an administrative district in southern Malawi. The results were analysed using a theory of curriculum implementation developed by Rogan and Grayson (2003). This theory has three interrelated constructs namely Profile of Implementation Capacity to Innovate and Outside Support. The study found that there were inadequate Outside Support and Capacity to Innovate which resulted in low level Profile of Implementation. Underqualified teachers in low resourced schools said the topics were difficult, but tried to teach them as presented in the syllabus. On the other more qualified teachers in better resourced schools left out many of the objectives in their teaching, although they saw them as easy. Although teachers appreciated the value of the new topics in assisting learners in understanding and skill acquisition, they showed generally more negative perception of the new topics with remarks such as difficult, boring and irrelevant. They felt they needed in-service training on the teaching of the new topics and provision of more resource materials for them to teach more effectively.

Background and Purpose of Study
In the Malawi Junior Secondary Biology curriculum of 2000, in addition to regular biology topics comprising Plant biology, Human and Animal biology, Human diseases, Genetics and Evolution and Environment, new content free topics, such as Thinking, Study, Investigative and Problem Solving skills were introduced to assist learners become better learners. This study was done to find out teachers’ perception and experience in teaching these new topics, as a way of gaining insight into the implementation of these new curriculum topics.

The need to introduce study skills was highlighted by the work of Davies and Greene (1985) which showed that science learners have difficulties using science texts. Generally, science texts are difficult to read because the language is impersonal and complex in structure. There is concentration of concepts, with limited elaboration. Furthermore, unlike in literature where learners are assisted by teachers to focus on key issues, science teachers tend to offer limited assistance to learners in the use of textbooks. Davies and Greene (1985) devised a reading scheme called “Directed Activities Related to Texts (DARTS), whose aim is to help learners acquire skills of getting information from secondary sources. The new Biology syllabus included DARTS with the aim that these skills will eventually become part of learners’ repertoire of study skills.

The thinking skills introduced in the new syllabus were derived from the works of Adey and Shayer (1994), Kunje (1987), Mbano (2001, 2003a). Using Piaget’s cognitive development theory (Inhelder and Piaget, 1958), Shayer and Adey (1981) showed that much of secondary school science would require formal operational thinking, yet less than 20% of learners in
secondary school classes attain this level of thinking. In view of this problem, Adey, Shayer and Yates (1989) devised an intervention programme, called Cognitive Acceleration through Science Education (CASE), which aims to increase the proportion of formal operation thinkers in secondary classes. These lessons were successfully adapted to Malawi schools (Mbano, 2001, 2003b, Mbano, Nampota and Dzama, 2005). The thinking skills component of the syllabus enhances the formal operational thinking competence necessary for the study of science.

Consistent with most science curriculums, which endeavour to foster appropriate attitudes, thoughts and approaches, investigations and problem solving in science were introduced as stand-alone topics in the syllabus. In the previous syllabus these topics were not addressed directly, it being assumed that if the content topics are taught correctly learners would contingently acquire skills for doing scientific investigations (Malawi Certificate of Education and Testing Board, 1972). However, research has shown that there is need to include this content in order for teachers to give it the required attention (Gott and Duggan, 1995). Consequently, the current Biology Syllabus describes the content of this topic fully.

When the new curriculum was being introduced orientation workshops were organised for the teachers. Furthermore, locally written textbooks have been produced such as Mhlanga, Ndolo and Mbano (1998) Strides in Biology, Medi and Meredith 1998) The new Junior Certificate Biology which have addressed these topics; this is in line with requirements for any core subject in the syllabus. An analysis of JCE examinations shows that these topics are tested; for example in 2003, 2004, 2005 and 2006 examinations these topics accounted for 21%, 8%, 21%, and 21% of the examinations’ total marks respectively. This shows that the topics have been incorporated in the Biology curriculum.

In Malawi, education is centrally managed with same structure in all districts, and learners in public schools follow a national curriculum. The public sector has two main categories of secondary schools: Conventional Secondary Schools (CSSs) and Community Day Secondary schools (CDSSs). Unlike CSSs, CDSSs started out as distance education centres and were in 1998 converted into face to face secondary schools by a government directive. However, the change in status from centres of distance education to CDSSs occurred without accompanying improvement in resources. Consequently, CDSSs are poorly resourced with inadequate classrooms, teachers, science laboratories and textbooks. Learners in these schools do not perform as well as those in conventional schools on national examinations. This study compared how teachers in CDSS and CSS perceived the new topics in Biology.

Problem Identification and Research Questions

There is often a mismatch between the intended and implemented curriculum (Cuban, 1993). Since the topics of study, thinking, investigative and problem skills are new in the curriculum and teachers did not learn them as school learners, nor did they study them during their teacher education, it is likely that they lack content and pedagogical knowledge and skills to teach the topics effectively. Furthermore, since the topics do not have the normal biological content some teachers may not easily perceive their relevance. In addition, the orientation workshops for the new syllabus being brief, lasting few days and with no follow up, it is quite possible that these topics were not have been addressed adequately. It is therefore hypothesised that the teachers will have negative attitude to the topics and so may not teach them effectively. This study explored the following research questions:

How easy or difficult do teachers perceive the teaching of the topics to be?
Of what value do teachers attach to the topics?
What difficulties do teachers encounter in teaching the topics?
What support did the teachers receive in implementing the new curriculum?
How could the teaching of the topics be improved?

**Theoretical considerations**

It is common in a curriculum implementation study to consider three dimensions of the curriculum namely; intended, implemented and attained curriculum ((Martin and Kelly, 1996; Travers and Westbury, 1989). The intended curriculum can simply put be represented at subject level by the syllabus. The implemented curriculum refers to practice and activities at classroom level. The attained curriculum represents what learners have learnt (Schimdt et al, 1996). In this study the intended curriculum is represented by the description of the new topics in the syllabus, the implemented curriculum could be represented how topics are rendered in textbooks and taught in classrooms and attained curriculum what skills the learners achieve. However this conceptual framework is commonly seen as deficient model, documenting the gap without explaining how it comes about and how it can be bridged. Rogan and Grayson (2004, 2003; Rogan, 2007), however, have developed a theory, drawing on school development, education change and science education literature, for implementing curriculum change in developing countries, which has three interrelated constructs namely Implementation Profile, Capacity to Innovate and Outside Support (see Figure 1).

Implementation profile focuses on the change that is desired to take place and how it is going to happen. It takes into account existing practices and skills and maps a number of ways to reach the desired change. In the case of this study the sub components of the Implementation Profile would include active learning approaches, Thinking skills, Investigative and problem solving and Study skills. Capacity to Innovate focuses on factors in the school that can hinder or foster the change. They usually include physical resources, teacher factors, learner factors and school management. In this study this would include presence of science laboratories, teacher qualifications, and continuing professional development (CPD) in the schools. Outside Support focuses on inputs from the Ministry of Education and community. In this case this could include textbooks, teacher’s guide, orientation of teachers, and supervision of teachers.

The theory incorporates concept of Level of Use from Hall and Loucks (1977) which has four main stages namely Orientation and Preparation, Mechanical and Routine Use, Refinement and Integration, and Renewal. During Orientation and Preparation Level teachers become aware of the new curriculum and may find out more and acquire syllabus and textbook as they prepare to teach. At the level of Mechanical and Routine use teachers teach according to what the developers want without modification or adaptation to local context. During the third stage of Refinement and Integration teachers collaborate with colleagues and use the curriculum flexibly, harnessing its strengths and minimising its weakness to meet their local needs. In the final stage of Renewal teachers make major changes to the curriculum in order to make it more effective. Rogan and Grayson (2003) have given examples of the four levels for the three constructs and their subcomponents without necessarily spelling out how those levels are arrived at.
The Rogan and Grayson (2003, 2004) theory of curriculum implementation not only describes the gap between intended and implemented curriculum, but explains how the relationship between the three constructs bring about the level of implementation at each point. Furthermore, the implementation process is seen as an incremental process, building upon current practices. They have adapted Vygostky’s concept of Zone of Proximal development (ZPD) to curriculum process to develop the concept of Zone of Feasible Innovation (ZFI). ZFI refers to gap between current practice and the demands of the new curriculum. They suggest that there is need for teachers to take small incremental steps, just ahead of current practice in order to successfully implement a new curriculum. They propose that curriculum change implementation is more likely to be successful if it is school based.

In a review of curriculum studies in mathematics and science using Rogan and Grayson Curriculum Implementation Theory, Lelliot et al (2009) found that most studies focussed on the two constructs: Implementation Profile and Capacity to Innovate. There were few studies on Outside Support. However in Malawi Outside Support would be a main issue in determining the extent of implementation of a new curriculum.

**Method**
The study used a self-report questionnaire on teacher’s perceptions of teaching the new topics. This was considered relevant because the purpose of research was to find out the
implemented curriculum through soliciting teachers’ views and experience of teaching the new topics. Furthermore, there was comparison between CDSS and CSS teachers.

The questionnaire had four parts. The first part elicited personal details and school characteristics from teachers. The second parts listed the objectives of the new topics and requested teachers to indicate the level of difficulty. The third part required teachers to indicate level of support they had received relating to new topics. The final section was an open-ended inquiry into their perception of the topics. The validity of the questionnaire was examined by a science education expert. The questionnaire was piloted on four teachers, two from CSS and two from CDSS.

The population of the study comprised all Biology teachers in public secondary schools in Zomba. There are 26 public secondary schools in Zomba, of which 9 are CSSs and 17 CDSSs. All CSSs participated, and 11 from the 17 CDSSs were randomly selected. Questionnaires were administered to Forms One and Two Biology teachers in the 20 schools (40). Of these, 32 teachers completed the questionnaires, representing 80% response rate.

Quantitative parts of the questionnaires were entered into a spreadsheet and results compared for the two categories of schools using frequencies and students’ t tests where applicable. Qualitative parts were analysed qualitatively by looking for recurring themes.

Results
Outside Support
Table 1 presents the frequencies of syllabus, textbooks and teacher’s guide availability, teacher orientation and supervision.

<table>
<thead>
<tr>
<th></th>
<th>% Teachers</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Syllabus</td>
<td>CDSS n =18</td>
<td>CSS n =14</td>
<td>All</td>
</tr>
<tr>
<td>Textbook: Strides in Biology</td>
<td>56</td>
<td>93</td>
<td>72</td>
</tr>
<tr>
<td>Teacher’s Guide for Strides in Biology</td>
<td>50</td>
<td>43</td>
<td>47</td>
</tr>
<tr>
<td>Textbook: New Junior Biology</td>
<td>56</td>
<td>93</td>
<td>72</td>
</tr>
<tr>
<td>Teacher’s Guide for New Junior Biology</td>
<td>5</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>Orientation to New Syllabus</td>
<td>22</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Orientation to New Topics</td>
<td>11</td>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td>Supervision</td>
<td>50</td>
<td>29</td>
<td>41</td>
</tr>
</tbody>
</table>

The results in Table 1 show that not all teachers had the new syllabus, textbooks and teacher’s guide. Furthermore very few were oriented to the new curriculum and topics. Supervision of teachers was rather low. Outside support to a school implementing a new curriculum in Malawi would mainly be provided by the Ministry of Education at central government and division level. The kinds of support are provision of syllabus, textbooks, teachers’ guide, orientation to the new syllabus and the teaching of new topics, and supervision in form of inspection and advisory services. At basic level for textbooks it is expected that at level one that all teachers would have a full complement of syllabus, recommended textbooks and teacher’s guide and supplementary materials. At a second level a school should have enough copies of recommended textbooks in order to organise classroom activities using them. At higher levels there should be adequate supplementary textbooks for teachers to use in lesson preparation. From the results it would seem that only very few of teachers reported to have been at the basic level.

The second aspect of Outside support would be how much help do teachers get from the textbooks? The New Junior Certificate Biology and Strides in Biology are recommended
books for Junior Certificate in Education (JCE). Strides in Biology books were purposely written for the new syllabus and contain extensive sections that address all the objectives in the syllabus. The New Junior Certificate Biology, an adaptation of a previous book to the new syllabus, has a short section comprising two chapters that address 8 out of 24 objectives of the new topics. 39% CDSS teachers and 57% CSS teachers said the textbooks treated the new topics adequately. Those who said textbooks are not adequate indicated that they needed more information in order to make notes for the learners.

The third aspect of Outside support is provision of continuing profession development (CPD). It is expected that the Malawi Institute of Education (a curriculum development centre) would orient all teachers to the new syllabus the teaching of the new topics in order to get them started in implementing the new curriculum. This would be followed by Ministry of Education’s support for schools to do school based In Service Training (INSET) to enable to plan together and support each other in implementing the new curriculum. In this way they will be able to eventually review the instructional materials and develop their own. The results indicate that few teachers attended orientation workshops for the new curriculum and topics and there were no indications of school based INSET. The work of Rogan and Grayson (2003; 2007) has shown that orientation of teachers and school based CPD are critical in implementing curriculum change. It would seem this aspect has been neglected in Zomba. In most cases some teachers are trained at training workshops but fail to implement school based INSET because of lack of outside support at this level. The final category is in monitoring and evaluation in terms of inspection and supervision was hardly done.

Capacity to Innovate

Teacher and School Characteristics

CDSSs have no laboratories, whilst CSSs have. Furthermore, CDSSs have less qualified teachers than CSSs (See table 2). For example, in CDSSs there are 33% teachers not qualified to teach in secondary school, whilst in CSSs all teachers have basic qualifications. However 61% CDSS and 71% CSS teachers felt qualified to teach the Biology.

Table 2 Teacher qualifications

<table>
<thead>
<tr>
<th>Qualification</th>
<th>CDSS n =18</th>
<th>CSS n =14</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSCE and Primary Teacher Certificate</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>Diploma in Education</td>
<td>28</td>
<td>36</td>
</tr>
<tr>
<td>Degree in Education</td>
<td>39</td>
<td>64</td>
</tr>
</tbody>
</table>

Table 3 compares Class size, Teaching load and experience in CDSS and CSS. The class sizes, teaching loads and experience are similar in the two types of schools.

Table 3: Class size, Teaching Load and experience

<table>
<thead>
<tr>
<th></th>
<th>CDSS n =18</th>
<th>CSS n =14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class size</td>
<td>49</td>
<td>47</td>
</tr>
<tr>
<td>Teaching Load</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>Teaching Experience</td>
<td>11</td>
<td>6</td>
</tr>
</tbody>
</table>

The construct of Capacity to Support Innovation mainly focuses on school factors. This study focussed on availability of laboratory, class size, teacher qualifications, experience and teaching load. It would seem that the Capacity to Innovate for CDSS is very low, with no laboratories, 33% of teachers underqualified. On the hand CSS have better Capacity to
Innovate with laboratories and better qualified teachers. In both types the class sizes are generally large, which would pose a challenge in teaching the new topics which require active learning approaches. Teacher’s experience is medium and this may make them as easily amenable to change.

Implementation Profile
In this section the teachers were asked to rate how easy or difficult the new topics were to teach. They were also given opportunity to indicate if they had not taught the topic or attained the objectives. Table 4 gives the results.

<table>
<thead>
<tr>
<th>Objective</th>
<th>CDSS (n=18)</th>
<th>CSS (n=14)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Difficult</td>
<td>Easy</td>
</tr>
<tr>
<td>Thinking skills</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present data in tabular and graphic form</td>
<td>17</td>
<td>78</td>
</tr>
<tr>
<td>Recognise variations amongst organisms of the same species</td>
<td>5</td>
<td>78</td>
</tr>
<tr>
<td>Summarise biological data in terms of bar charts, histograms, means, median and range</td>
<td>6</td>
<td>72</td>
</tr>
<tr>
<td>Explain the importance of sampling in Biology</td>
<td>5</td>
<td>67</td>
</tr>
<tr>
<td>Identify Variables</td>
<td>17</td>
<td>66</td>
</tr>
<tr>
<td>Recognise irrelevant variables in given Data</td>
<td>28</td>
<td>56</td>
</tr>
<tr>
<td>Deduce correlational relationship between variables</td>
<td>28</td>
<td>55</td>
</tr>
<tr>
<td>Deduce mathematical relationships</td>
<td>28</td>
<td>50</td>
</tr>
<tr>
<td>Suggest explanations for observed relationships</td>
<td>39</td>
<td>50</td>
</tr>
<tr>
<td>Recognise that large samples give better representation</td>
<td>17</td>
<td>50</td>
</tr>
<tr>
<td>Use mathematical relationships or graphs to make predictions</td>
<td>50</td>
<td>39</td>
</tr>
<tr>
<td>Design experiments with proper Control</td>
<td>55</td>
<td>39</td>
</tr>
<tr>
<td>Deduce qualitative relationships</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Formulate hypothesis to test suggested explanations</td>
<td>50</td>
<td>28</td>
</tr>
</tbody>
</table>

**Study skills**
Describe specimen using well labelled                                          6  89  5  0  86  14
diagrams

Summarise information from books ... 22 67 11 0 86 14
Recognise assumptions in statements 28 55 17 7 57 36
Distinguish facts from opinions 22 67 11 28 44 28
Give evidence for assertions 33 56 11 21 50 29
**Investigative skills**
Carry out investigations 22 61 17 14 43 43
Write reports on investigations 33 50 17 28 36 36
**Problem solving**
Solve problems in everyday life 17 72 11 7 57 36

**Thinking Skills**
Generally, more teachers in CDSS indicated that they found these topics difficult than teachers in CSS. The following objectives were rated easy by teachers from both types of schools: identify variables, present data in tables and graphs, deduce mathematical relationships between variables, suggest explanations for observed relationships, recognise variations in organisms, summarise biological data in terms of means, median, range, charts and histograms, recognise the importance of taking samples. All these objectives are encountered frequently, especially in mathematics. Therefore, one would expect them to be easy as both teachers and learners would have plenty of experience. The concepts that deal with biological data (variation, sampling and describing distributions), though perceived to be easy by both groups of teachers had not been taught by many. This is not surprising as they are not commonly done in most secondary curriculums and get introduced in statistical courses at tertiary level (Mbano, 1990). More teachers in CDSS indicated that they found the teaching of objectives ‘making prediction’, ‘formulating and testing hypothesis’ and ‘designing investigations’ difficult than teachers in CSS. It may be that teachers in CDSS, being less qualified find these objectives difficult because they are not familiar with investigations. Overall ‘correlation’, ‘design investigations’, ‘formulate and test hypotheses’, ‘sampling,’ were recorded as not taught by most of the teachers.

**Study skills**
The two objectives on study skills; summarise information from books, and to describe specimen using well labelled diagrams were rated as easy by both groups of teachers. Furthermore, the number of teachers who had not taught was small. It would be seem teachers are confident about teaching this topic. However the objectives on judging statements, such as whether they were factual or opinions, recognising assumptions in statements and giving evidence for assertions had not been taught by many teachers from both types of schools.

**Investigative and problem solving skills**
The two objectives in investigative skills: carry out investigations and write reports are reported easy and generally taught by CDSS teachers. Problem solving skills, although rated easy by both group of teachers, more CSS teachers do not teach it than CDSS teachers.

**Teachers’ perceptions of the value, difficulties and learners’ response**
The questionnaire had an open ended section asking teachers what they saw as the value of the new topics, difficulties they experienced in teaching it, and suggestions for improvement. Table 5 gives the frequency of categories of the responses

Table 5: Teacher’s perception of the value of the new topics
Many teachers saw the value of the new topics as “Deals with real life situations”, assisting in understanding and acquisition of skills. There was not much consensus on the value of these new topics such that it seems each teacher creates his own value. This may be symptomatic of lack of knowledge and experience in the topics, which point to lack of orientation. It also means that the teaching varied from teacher to teacher, depending on their perception. Table 6 gives results of how the teachers felt about teaching the new topics.

<table>
<thead>
<tr>
<th>Perception</th>
<th>CDSS (n =18)</th>
<th>CSS (n =14)</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dealing with real life situations</td>
<td>33</td>
<td>36</td>
<td>34</td>
</tr>
<tr>
<td>Helps in skills acquisition</td>
<td>39</td>
<td>21</td>
<td>31</td>
</tr>
<tr>
<td>Helps in understanding theory and knowledge</td>
<td>28</td>
<td>14</td>
<td>22</td>
</tr>
<tr>
<td>Help in understanding biology and science</td>
<td>11</td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td>Improves thinking and reasoning</td>
<td>17</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>Solves problems</td>
<td>11</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Teaches investigations</td>
<td>17</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Helps in practical biology</td>
<td>5</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>Other comments</td>
<td>27</td>
<td>28</td>
<td>28</td>
</tr>
</tbody>
</table>

There was more negative perception of teaching these topics, with comments such as “difficult, involving, too much work, not Biology, lack of teaching and learning resources”, and “not interesting” accounting for 44% of the responses, whilst positive comments such as “good and interesting, important and helpful, confident, have knowledge”, and “easy” making up about 26% of comments. Some perceptions separated teachers in CDSS from teachers in CSS; for example, 36% of teachers in CSS found the topics “not interesting /boring”, whilst none of the teachers in CDSS stated this. 44% of teachers in CDSS found them “difficult to teach” whilst only 14% of the teachers in CSS mentioned this. 28% of the teachers in CSS complained that there was “too much content for the allocated time”, but only 11% of the teachers in CDSS said this. 44% of the teachers in CDSS teachers mentioned “lack of resources”, but none of CSS teachers indicated this. 44% of the teachers in CDSS said that their “learners find them difficult because they are slow learners and are unfamiliar with the situations”.

It would seem most of these differences are a reflection of what obtains in the schools. CDSS teachers operate in more poorly resourced schools, such as with lack of laboratories, with poor qualification, and slower learners who scored lower marks in the Primary School Leaving Certificate (PSLC) examinations. With such negative attitude to their learners’
ability, one wonders how much of what goes on in CDSS and student achievement is not as a result of this self-fulfilling prophecy.

More than 50% of the teachers felt that the Ministry of Education (MOE) should provide more resources and orientation for the teachers. Some suggested that the new topics should be integrated with regular Biology topics by spreading them throughout textbooks. Furthermore, they suggested that activities should be relevant to learners’ experience and previous knowledge. In addition, the topics were seen to be too long and to take too much time. Accordingly, there were suggestions to reduce them, both in the syllabus and in textbooks by leaving out some objectives such as judging statement which are seen to belong to English.

Using Profile of Implementation (Rogan and Grayson, 2003) it is rather difficult to fit the two groups of teachers into levels. Teachers in CDSS seem to be at the level of Mechanical and Routine use, as are attempting to teach all the topics. Teachers in CSS, on the other hand, may either be at the preparatory stage where they are still finding out about the new topics and not teaching or at refinement and integration stage where they choose and pick which topics to teach according to their needs and context. The comments on how the teaching could be improved show that the teachers have good ideas on how to implement the curriculum taking into account their needs and contexts. This highlights to the importance of school based INSET where such ideas could be put to use.

Discussion
The study reveals several weaknesses in the implementation process using the theory proposed by Rogan and Grayson (2003). Firstly there seems to be weak Outside Support and Capacity to Innovate leading to low level of Profile of Implementation. With regards to Outside Support, not all learning materials were available to teachers and learners. Furthermore there was no appropriately planned CPD. Rogan and Grayson’s work has revealed that school based INSET achieves better outcomes than externally managed CPD (Rogan and Grayson, 2003). Furthermore they have developed the concept of ZFI which seems also to work well at school level, as teachers can take into account both context at the school and current practices. The school factors to support innovations are very weak in CDSS with poorly qualified teachers, no laboratories and learners with poor achievement at primary school level. Although teachers worked hard to implement the curriculum their efforts were frustrated by lack of support both in school and externally. CSS have better in school capacity to innovate, however their implementation is hampered by lack of school based implementation plans.

Limitations of the Study
This is a case study was limited to Zomba schools; hence the results cannot be generalised to other areas. The use of questionnaires limits the depth of information that can be collected on teachers’ experience in teaching the new topics.

Implications of the Study
The study using Rogan and Grayson (2003) Theory for Curriculum Implementation suggests that schools in Zomba had low implementation profile because of low Capacity to Innovate and poor Outside Support. It would seem that the main constraint was inadequate support in terms of instructional materials and CPD. Although work in curriculum implementation point to the importance of school based CPD there was no evidence of any plans or activities in this. In order to authentically implement a new curriculum there is need to invest in physical resources, instructional material and CPD.
References


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A framework for Understanding and Reflecting on Students’ Knowledge Structures about Aqueous Acid-Base Solutions

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Abstract
One of the challenges facing science teachers in their attempt to enhance learning is their understanding of students’ pre-instructional conceptions. In order to understand these conceptions teachers need grounded and innovative approaches to assessment in order to access knowledge structures. That is, they need accurate ways of understanding how students organise concepts and principles of the topics of interest as they attempt to construct understanding and/or generate meaning during learning. In this paper a framework for assessment of knowledge possession and application (AKPA) to assist in understanding students’ knowledge structures is demonstrated with selected concepts and principles from the topic “aqueous acid-base solutions”. An in-depth qualitative analysis is used to reflect on students’ representations of the topic. The reflection demonstrates how students’ knowledge structures and their organisation may be established to guide conceptual change and enhance students’ future learning. The framework developed from this analysis captures the following constructs: knowledge features, functioning, conceptual change and knowledge effects on learning. In this paper I argue that relevance and power of this framework for assessment lie in its potential to illuminate students’ abilities to construct understanding in their future learning and to enhance the accuracy of the teacher to identify alternative conceptions in the topic. The grounded and innovative nature of this framework presents aspects of pedagogical approaches that are rarely addressed in relation to knowledge structures associated with aqueous acid-base solutions and many other topics in chemistry.

Key words: conceptual change; knowledge structures; knowledge representation; concepts; aqueous acid-base solutions; prior knowledge

Introduction
The major challenge facing science teachers in the changing and diverse student population is not necessarily their lack of subject matter knowledge but rather making appropriate choices of the moment and material to teach at any given time. Although subject matter knowledge is an important part of their pedagogical content knowledge, the main challenge lies in the teacher knowing exactly what, when and how to teach it. Knowing an appropriate lesson design for a particular student cohort requires the teacher’s ability to understand students’ readiness or potential to engage productively in learning material prescribed at any instance of the teaching and learning process. In other words the teacher needs the understanding of some of the variables intervening (both inhibitive and enhancing) in student’s learning. Ausubel (1968) identified prior knowledge or the knowledge the student already possesses as one of and the most important factor determining the success or failure of learning. In fact, Vosniadou (2008) posits that in order for students to learn successfully, they need to first restructure their extant knowledge. That is, fundamental to successful learning is the process of conceptual change. From the teacher’s perspective learning may be enhanced through his/her intervention in the conceptual restructuring processes. However, the teacher must first establish the students’ state of conception in order know what is to be changed and how it is to be changed. The state of conception is defined and may be understood by students’ existing knowledge structures or the structure and functioning of their concepts. Without this
understanding any prescription of teaching strategies, methods or learning material may be a futile exercise. This understanding may be established through a regular assessment of students’ pre-instructional conceptions before any new topics are taught.

In light of the importance of students’ prior knowledge structure and organisation in learning there is therefore the need for an assessment of the knowledge that students possess before and/or in the process of teaching to ascertain the state of their knowledge structures. In this paper a framework is demonstrated for this purpose. This framework may offer an appropriate and accurate tool for an in-depth assessment and understanding of students’ knowledge structures from the concepts they possess and/or use in the learning of and about aqueous acid-base solutions or any other science topic.

Theoretical Background
The importance of prior knowledge has been reported about in many research studies. The reports were mostly concerned with the inhibiting and enhancing characteristics of prior knowledge on learning (e.g. Dochy, 1992). In their study Hailikari, Katajavuori and Lindblom-Ylanne (2008), report about the positive aspects of prior knowledge. Their contention is that prior knowledge may only enhance learning if it is structurally well-organised. They argue that in order to “initiate inference, conceptualization, and the acquisition of principled understanding” prior knowledge needs to be coherent (p. 1). What this contention implies is that teaching is in a way a process of helping students to form concepts that may be used to build (organise) new concepts and/or new knowledge. In the teaching of abstract chemistry concepts for example, understanding the organizational structure of students’ concepts would add to the teacher’s armoury to address students’ learning difficulties. Jaber and BouJaoude (2012) in their study of Lebanese students learning chemistry identified the triangular nature of matter as impeding learning in that students found it difficult to conceptualise. Understanding students’ knowledge structures or the manner in which they possess and use their concepts would help the teacher access students’ representation of chemistry concepts such as in acid-base aqueous solutions.

Concept possession is important in understanding structural organisation of knowledge. That is, it is the teacher’s window into the students’ state of conception at any given stage of learning. Concept possession is the ability to recognise one, know what it is for, and how it works (Peacocke, 1992). It highlights levels of one’s knowledge about something at any particular stage of learning. The emphasis on concept possession is based on Reif’s (2008) assertion that concepts are building blocks of knowledge. If a science teacher has access to the state of concepts or conception he/she has a vantage position to observe and subsequently influence the transformation or reorganization of the students’ knowledge structures into a new structures and competence levels (Lappi, 2012). The most important and imperative thing currently in structural organisation of knowledge is how to access it.

Assessment Framework for Accessing Pre-instructional Conceptions
Constructivists view learning as a construction process the individual student engages in during learning (Fosnot, 1996; Ishii, 2003). As learning implies a change from one state of conception to the other the construction process needs to therefore involve changes in concepts used initially to new ones in the knowledge building process. In other words this may be the addition of other concepts to enrich existing ones (Vosniadou, 2008). Lappi (2012) refers to this transformation of the initial state of conception to the final conception as conceptual change. Vosniadou (2008) on the other hand argues that conceptual change needs
to be domain specific as “it examines distinct domains of thought and attempts to describe the process of learning and development within these domains” (p.48).

This paper presents a framework (Fig.1) that aims to assess students’ knowledge structures and the changes they undergo during a process of knowledge construction. Although the nature of knowledge makes it difficult to capture, an attempt is here made to estimate as closely as possible the knowledge students possess at the instance of assessment. Assessment would therefore be a requirement before any teaching could be undertaken on any topic and focus on concepts as possession by students. In this study concept possession is described using both Peacocke’s (1992) and Ferrari and Elik’s (2003) descriptions. In their description Ferrari and Elik (2003) use a *synthetic* and *dialectic* approach. They propose a *two factor* theory with internal and external components. These components are said to play complementary but different roles in the students’ learning process. The components define a *psychological* explanation of concepts and determine ‘how the concepts are applied in the world’ respectively (p.25). That is, the psychological aspect describes mind processes whereas the physical aspect defines the real-world truth conditions of the concept in the environment or context in which learning takes place. Possession of a concept must therefore demonstrate a psychological explanation and a physical application of a concept or of related knowledge (Ferrari & Elik, 2003). It is also important to indicate that as concept possession is assessed the *fluid, dynamic and interactive* (Treagust, 1995) nature of learning or ‘knowing’ must be taken into consideration. That is, knowledge is not static it changes with every passing moment (Dochy & Alexander, 1995) at anytime the student is engaged with his/her concepts to construct new knowledge.

![Figure 1: A Framework for Assessment of Knowledge Possession and Application (The AKPA Framework)](image-url)
In addition, it must also be said that knowledge or related concepts may only be ‘accurately’ assessed as explicit knowledge although there is the inherent part played by tacit knowledge. Explicit knowledge is the knowledge that can be formalized, codified and easy to store and retrieve (Brown & Duguid, 1998). Tacit knowledge on the other hand is intuitive, context dependent, personal in nature and very difficult to define, isolate and/or assess (Brown & Duguid, 1998). In fact, Botha, Couts and Roth (2008) view tacit and explicit knowledge as a spectrum rather than individual definitive points of knowledge. In the framework the two are indicated as mediating between interacting of structure and functioning. This is a clear sign of the slippery nature of knowledge described earlier in this study. Finally the learning process or knowledge construction is in the context of this framework assessed with a focus on the structure organisation and functioning of the student’s existing or prior knowledge. The teacher’s understanding of student’s existing knowledge will then acts as another tool in the teacher’s repertoire of supporting mechanisms for teaching.

Description and Explanation of Aspects of the Framework

The framework for assessment of knowledge possession and application (AKPA) consists of five (A, B, C, D & E) areas which may be regarded as important and necessary to define and understand knowledge structures or the knowledge that students possess and/or use in the process of constructing understanding and generating meanings.

**Functioning (A):** This area describes the usefulness of knowledge. Functioning is one of the two criteria Smith (1991) uses for determining if one understands a concept. That is functioning illuminates on the student’s understanding of knowledge or idea. In other words functioning indicates if the student can use knowledge successfully in performing significant tasks. This section focuses on how one’s knowledge functions especially when a student performs tasks or attempts to construct new understanding in a learning process.

**Structure (B):** Structure describes ‘Connectedness’ of concepts in a student’s knowledge structure. It is one of the criteria Smith (1991) uses in understanding knowledge. It has to do with the structure and/or the relationships of the components constituting this structure. This criterion describes “connectedness” that is initiated when an idea is understood. It therefore helps in assessing the extent that the student can appropriately represent concepts and connect them with his or her prior knowledge. In other words this area deals with structural organisation of the student’s knowledge.

**Knowledge/Concept Possession(C):** This area of the framework is central to the knowledge the student has acquired or his/her extant knowledge. It is central because it carries the knowledge that the student has at the time of learning and/or assessment. The type (e.g. declarative or conceptual) and form in which this knowledge is possessed determines to a large extent how it is to be used in processing new knowledge.

**Knowing (D):** Wilson (1993) describes learning in terms of ‘knowing’. This is the process when the student experiences transformation of his/her extant knowledge or concepts into new understandings. The knowing process (Wilson, 1993) is integral and inherent to every day student activities where different types and forms of knowledge (e.g. explicit or tacit (E)) interact dynamically.

As indicated in the framework, all its parts are inherent in ‘knowing’. That is, knowing is fluid, interactive and dynamic. Thus being aware of the different types of knowledge their structure, functioning and their interaction in the learning process is important for theoretical and practical understanding of how knowledge is represented and for teaching and learning purposes (Shuell 1985).
Illustrating the Assessment Process, Results and Discussions

Earlier in this paper the difficulty of accurate assessment of knowledge was acknowledged. Knowledge is dynamic interactive and fluid and also a combination of both explicit and intuitive tacit knowledge. It is among others this nature that makes knowledge such a difficult and accurate to assess phenomenon (Brown & Duguid, 1998). However through its functioning we may understand knowledge construction during learning. Learning or knowing is embedded in the functioning and further construction of new knowledge. With this information the teacher is able to utilise the state of student’s knowledge structures for appropriate selection of teaching material and methods.

Below information drawn from an assessment of the student’s knowledge of aqueous acid-base solutions is illustrated. The data was qualitatively collected using a prior knowledge test (T), interview and observation (I&O) from practical work activities (P). different methods were used to ensure an accurate assessment of their knowledge structures and subsequent conceptual change. According to Lappi (2012) conceptual change “occurs when learning does not result merely in more accurate factual knowledge…but a new conceptual framework, which one uses to organise that knowledge, to interpret phenomena and to make sense…”. Hence the need for a multimethod assessment to enhance a more representative data of students’ knowledge structures and its functioning.

Illustration of the Assessment of Aqueous acid-base solutions knowledge structures

The data presented in the cluster below is meant to illustrate and reflect on one student’s structural organisation or functioning of concepts relating to aqueous acid-base solutions during a titration process. The analysis of the sample was meant to determine acidity (in m/v %) of an aqueous solution of commercial vinegar. The data about this student was collected from different sources as indicated by the different methods used. The data cluster reflects a chunk of information reflecting text depicting concepts and how they relate in the student’s conceptual framework. Therefore the analysis was meant to reveal structural organisation and functioning of different concepts on the analysis of an aqueous acid-base solution.

Data Presentation and Results

Data Cluster (Data Collected from Different Sources)

Keys
Question (Q); Student Response (SR); Structural Organisation (SO); Function (F); Test (T); Interview (I) Practical work (P) and Data Source (DS); 
[SO] = analysis focuses on structural organisation; [SO; F] = analysis focuses on both structural organisation and Functioning; [F] = analysis focuses on functioning.

Q.1: Differentiate between Arrhenius and Brønsted-Lowry acids. (DS: T)
SR.1: Arrhenius’ acids increase the concentration of H⁺ ions when dissolved in water while Brønsted-Lowry's acids are proton donors.

Q.2: You are told that an “aqueous solution is acidic”. What does this statement mean? (DS: T)
SR.2: It means the solution has a high concentration of H⁺ ions.

Q.3: As the hydrogen-ion concentration of an aqueous solution increases, the hydroxide-ion concentration of this solution will –
(1) Increase
(2) Decrease or
(3) Remain the same? (DS: T)
SR.3: Decrease. (No elaboration for the response)

Q.4: When HCl (aq) is exactly neutralised by NaOH (aq), the hydrogen-ion concentration in the resulting solution is…
(1) Always less than the concentration of the hydroxide ions;
(2) Always greater than the concentration of the hydroxide ions;
(3) Always equal to the concentration of the hydroxide ions; or
(4) Sometimes greater and sometimes less than the concentration of the hydroxide ions. (DS: T)
SR.4: Always equal to the concentration of the OH⁻ ions.

Q.5: Why is ethanoic (CH₃COOH) acid considered a weak Brønsted-Lowry acid? (DS: O&I)
SR.5: It is a weak acid … CH₃COOH is not ionised completely because there are still H⁺ ions within the CH₃COO⁻.

SO: F

Q.6: What is the difference between a strong and a weak Brønsted-Lowry acid? (DS: O&I)

SR.6: Acid that dissociates or ionises completely is an aqueous solution.

SO: F

Q.7: Presume that you are titrating a weak acid (e.g. CH₃COOH) and a strong base (e.g. NaOH). What would the expression "equivalence point" mean in this process? (DS: T)

SR.7: The amount of titrant is chemically equal to the amount of analyte.

SO: F

Q.8: Why (in the initial stages of a titration) is there a temporary colour change in a solution whenever the NaOH solution drops in the centre of the solution (analyte solution) during titration? (DS: O&I)

SR.8: Because it has reached the equivalence point.

SO: F

Q.9. What is meant by equivalence point? (DS: O&I)

SR.9: Amount of vinegar is equivalent to NaOH in the solution.

SO: F

Q.10: What is meant by endpoint? (DS: O&I)

SR.10: When we observe colour change.

SO: F

Q.11: What is the purpose of an indicator in a titration? (DS: O&I)

SR.11: To find the colour change and observe the pH of the solution.

SO

Snippets/excerpts from the practical work report (Practical work report)

Method

Pipette 10 ml of vinegar solution into a 100 ml volumetric flask.

Add deionised water to the graduation mark.

Pipette 25 ml of vinegar solution into a conical flask.

Titrate the NaOH solution into the conical flask until (the) colour changes.

Observation

At the beginning of the titration, there is a colour change at the centre of the conical flask.

As the process continues, the colour turned dark pink (endpoint). The colour change is due the indicator added …

Calculated percentage: 461% (estimated %: 4 to 6%)

Conclusion

% content of ethanoic acid in vinegar solution is very high [SO; F]

Q.12: Differentiate between a dilute solution of a weak acid and a concentrated solution of a weak acid. Illustrate your answer with a relevant example. (DS: T)

SR.12: Dilute weak acid does not produce gaseous gas while concentrated acid produces substances.

H₂CO₃ → CO₂ + H⁺
H₂CO₃ → H₂O²⁻ + HCO₃⁻

SO: F

Q.13: Calculate the molarity of HCl if it has a density of 1,057 g/ml and purity of 12% by mass. (DS: T)

SR.13: D = m/v; 1,057 = (12/100)/v

v = 0, 12351

= m/mv

= 0, 03 mol/dm³

SO: F

Q.14: Illustrate how 500 ml of a 6 M solution of NaOH may be diluted by a factor of 25. (DS: T)

SR.14: 6 x 500/25

SO: F

Q.15: What do you understand by the term "concentration"? (DS: O&I)

SR.15: Concentration is the ratio of moles per volume (n/v).

SO: F

Q.16: What do you mean by the term "dilute"? (DS: O&I)

SR.16: To reduce the concentration of vinegar.

SO: F

Q.17: What is the concentration of ethanoic acid in vinegar after dilution? Is it high or low? (DS: O&I)

SR.17: It is not yet known.

SO: F

Q.18: What happens if it adds the volume? (DS: O&I)

SR.18: It reduces the concentration.

SO: F
Table 1: Structural Organisation and Functioning Analysis of Students’ Knowledge Structures

The keys (e.g. [SO; F], [SO] or [F]) signify what has been analysed about a particular text. For example, if both symbols appear together then they indicate outcomes of analysis on structural organisation and functioning. However this does not mean one aspect may not be independently assessed. The ‘what’ and level of knowledge analysed depends on the type and/or form of knowledge the student demonstrated at any particular time or situation.

The assessment and analysis of the student’s knowledge structures for structural organisation and functioning are represented from two analysis approaches referred to as **intrinsic** and **extrinsic** in this paper. Intrinsic approach reflects the student’s meaning implied in his/her direct response to a question or event in his/her manipulation in a practical work activity. Extrinsic approach on the other hand would refer to the outcome of a synthesis of meanings across responses and events (i.e. text from other events and/or questions) as represented by the student. For example a response from Q.1 may imply a particular understanding about the student’s response in Q.5. In the table (Table 1) only the current (Initial Knowledge Structure State) knowledge structures are reflected. However, the table makes provision for data after transformation activities (i.e. Transformed Knowledge Structure State) and conceptual change.

Analysis and Discussions

Data analysis is based on AKPA features that make up the knowledge or concept possession (i.e. features that describe both declarative and conceptual knowledge). These features’ analyses the structural organisation and functioning of the student’s knowledge may be revealed and the nature and potential effect of his/her knowledge structures on learning reflected. Declarative knowledge describes the student’s ability (i) to recognise and describe a concept and (ii) to know what a concept is for and how a concept works. Conceptual knowledge (i.e. combination of procedural knowledge and conditional knowledge in this study) on the other hand describes (iii) what the concept is for and (iv) how the concept works. From these four functions of knowledge possession (see table 1) different combinations or matrices may be constructed to reveal a picture of the characteristics of both the structure and functioning of the student’s knowledge framework on aqueous acid-base solutions.

Description and Explanation
The information extracted in (SR.1) response to the first question (Q.1) was classified as [SO; F]. This classification is meant to reveal both the structural organisation and functioning of knowledge respectively. As both of the classifications are located within declarative knowledge they must be reflecting the student’s ability or lack thereof to recognise and describe a concept. In relation to the specifications (scientifically valid descriptions) of the two acid concepts, what are the characteristics of the student’s knowledge structures or framework? That is, is the student (based on the analysis) able to recognise and describe the two concepts?

First, it is imperative to indicate clearly the criteria for describing the two acid-base concepts. The criteria or specification of concepts is used as reference to the student’s aqueous acid-base solution concept representation. That is, (Sedumedi, 2008) “specific elements of the text in the form of concepts, meanings, thoughts, language and interpretations as presented by individual students” are matched with the scientifically valid descriptions (p.91).

Criteria and/or specification of concepts
Arrhenius Acid-Base Concept
According to Arrhenius acids are substances that when dissolved in water increases the H⁺ ions and bases are substances that when dissolved in water increases the OH⁻. That is, the Arrhenius acid-base concept is limited to aqueous solutions.

HCl (aq) → H⁺(aq) + Cl⁻(aq) HCl is an acid as the H⁺ ions are increased in the solution
NaOH(aq) → Na⁺(aq) + OH⁻(aq) NaOH is a base as the OH⁻ ions are increased in the solution

Brønsted-Lowry Acid-Base Concept
This concept is based on the notion that acid-base reactions involve the transfer of H⁺ ions from one substance to another. For example in water HCl acts as a substance that transfers H⁺ ion.

HCl(aq) + H₂O(l) → H₃O⁺(aq) + Cl⁻(aq)
In this relationship HCl donates a proton to H₂O i.e. it is an acid, H₃O⁺ is a base as it accepts a proton from the HCl.

Q.1: Differentiate between Arrhenius and Brønsted-Lowry acids.
RS.1: Arrhenius’ acids increase the concentration of H⁺ ions when dissolved in water while Brønsted-Lowry’s acids are proton donors.

Intrinsic Analysis (SR.1): In her response the student managed to recognise and describe the acid according to the both the Brønsted-Lowry and Arrhenius theories. That is, the structure of her representation of the two acids is consistent with the scientific description of the two concepts. What is also apparent in her response is the incomplete response to the question. The student could not mobilise (make functional) her factual knowledge of the two concepts to distinguish features that make the difference between these theories to complete the answer to the question.

Q.2: You are told that an “aqueous solution is acidic”. What does this statement mean to you? (DS: T)
SR.2: It means the solution has a high concentration of H⁺ ions.

Intrinsic Analysis (SR.2): The student’s response in this question demonstrates lack of accuracy in representing the facts about acidity. The word ‘high’ in her response assumes H⁺ ions to be the only ions in this aqueous acidic solution. This response indicates lack of imagination of what could be happening in an aqueous solution. That is, the knowledge’s structure limits her ability to restructure her extant concepts to construct a scientifically valid and functioning knowledge for an aqueous acidic solution. Is the student aware of what is meant by the term aqueous or what it means by ‘when dissolved in water’?

Strength and/or weakness of acids
In aqueous solutions acid-base reactions represent a competition for protons. That is, two acceptors of protons compete to attract protons. For example a strong acid in water will lose a proton more readily in water. In the same vein a weak acid will be less likely to lose a proton. Ethanoic acid (CH₃COOH) is less likely tolose a proton in water. Thus it is a weak acid.

HCl (aq) + H₂O(l) → H₃O⁺(aq) + Cl⁻(aq) : HCl acts as a strong acid in water; H₂O attracts a proton. It is a stronger base than Cl⁻ this reaction is more likely to happen.

CH₃COOH(aq) + H₂O(l) → CH₃COO⁻(aq) + H₃O⁺(aq) : CH₃COOH acts as a weak acid because H⁺ is more attracted to CH₃COO⁻ than it would with water; this reaction is less likely to happen.

Dissociation constants may also be used to explain acid strength (i.e. an acid is considered to be ‘strong’ if Ka is unity or greater).

Q.5: Why is ethanoic (CH₃COOH) acid considered a weak Brønsted-Lowry acid? (DS: O&I)
SR.5: It is a weak acid … CH₃COOH is not ionised completely because there are still H⁺ ions within the CH₃COO⁻.

Intrinsic Analysis (SR.5): The student’s response is partly valid. However reason for the first part of the answer clearly indicates her understanding of complete deionisation. This representation is not in alignment with the specification as explain in terms of the meaning of a weak acid. The concept of ‘complete deionisation’ demonstrates limited explanation during teaching of the concept. That is, the structure of her knowledge needs reorganisation for better functioning.

Extrinsic Analysis: Integrated Analysis of SR. 1, SR.2 and SR. 5
This part of analysis integrates analyses from the three responses. This is meant to demonstrate relationships and the effects of concepts different concepts on one another. The integration reflects the student’s knowledge structures. The relationship
may also be an indication of the fluid, dynamic and interactive nature of this student’s knowledge. Integration introduces a new permutation that connects concepts. The new permutation reflects another level and depth of analysis. The more permutation we introduce the deeper the analysis goes and the more understanding of student knowledge structures we achieve.

What is apparent in this integrated level of analysis is the ‘missing link’ in the student’s knowledge structure. It is clear that this student reasoning or lack thereof does not go deeper in utilising the microscopic level of the conceptualisation of matter as described by Johnstone, (2000a). That is, most of her shortcomings in terms of answering questions were at the micro level. That is the structural organisation of her knowledge of aqueous solutions had limitations and affected her reasoning capacity. Lack or limited reasoning capacity is a reflection of poor or no capacity to function. For example her first response (SR.1) was incomplete as she could not single out features that differentiated the two theories. This feature had to do with the limitation of the Arrhenius theory as it is only limited to aqueous solutions. Did the student understand the meaning or the concept of an aqueous solution? The student’s response (SR.6) gives an answer to this question (i.e. SR.6: Acid that dissociates or ionises completely is an aqueous solution).

Other responses in the data cluster may not have been used but the reader is encouraged to use them to create his/her permutations. Any permutation brings with it a wealth of information about the student’s state of knowledge structures. It also gives you an opportunity to see how deep knowledge structures may be assessed to inform you as a teacher how much work you need to do to ‘correct’ knowledge structures and enhance conceptual change.

Summary of Findings
The purpose in this study was to present a framework for analysis of knowledge possession and application. That is, it reports about how knowledge possessed by students may be accessed. Since knowledge is dynamic it is also important to attempt to assess knowledge when it is used or applied. The framework is organised in a way as to give access to knowledge in its use by relating aspects of the student’s responses to different questions in different contexts or situations. What is also important with the framework is that it enables us not only to assess knowledge. It enables us to assess different types of knowledge. This ability to assess different types of knowledge is important in classifying areas of knowledge that students find difficult to comprehend. In this way each problem of learning may be confronted with appropriate tools for solutions. In the example used in this study findings may be categorised according to the types of knowledge (i.e. declarative and conceptual) and also in terms of structure and functioning.

Conclusions and implications for teaching and learning
Assessment is an important part of the teaching and learning system. The development of the AKPA was meant to consolidate the importance of assessment in teaching and learning. As there are two major forms of assessment (i.e. formative and summative) the AKPA is more of an instrument focusing on the teacher’s capacity to conduct formative assessment. This is the case because its main objective is to help our understanding of the knowledge the student already has and how this knowledge may be changed with the aim to improve its structural organisation and functioning. The framework has therefore more meaning for conceptual change.

The use of the AKPA brings two important implications for teaching and learning. These are implication for the teacher and for his/her students. Implications for the teacher are that: The teacher will always have to ensure an in-depth assessment of prerequisite knowledge for the topics he/she intends to teach. Information drawn from the prior knowledge test (s) will enhance the teacher’s selection of teaching material and/or the design of his/her lessons. Implications for the student are that: The student will reflect on the status of the quality her/his knowledge and be motivated to improve areas of difficulty and
The student’s learning will be more specific as the assessment focuses on different types and areas of knowledge that the student may address more specifically and adequately to enhance conceptual change.

In conclusion the framework is an ideal tool to address the difficulty of comprehending abstract and complex subjects such as chemistry. In addition, the teacher will be able to learn more and interact more with his/her students than is currently the case.

Reference

